Alpine View Estates Drainage Master Plan

Douglas County, Nevada

August 2019

prepared for | Douglas County

PROFESSIONAL ENGINEER - STATE OF NEVADA
RICHARD M. WASKOWSKY
Exp: 6/30/2020
CIVIL
No. 25084

Date Signed: August 20, 2019

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1 INTRODUCTION

1.1 PROJECT PURPOSE

The Aline View Estates Drainage Master Plan (Study Area) was developed to meet two primary objectives. First – evaluate and identify existing flooding hazards within the project area by the implementation of a work plan which includes data collection, review of previous studies, information gathering from public agencies, and hydrologic and hydraulic modeling. Second – develop a series of flood mitigation concept recommendations with the goal of reducing the hazards identified in the first objective.

Each major task of the project is presented herein with a description of the technical approach, analysis results, interpretation of results, and applicability to the overall project purpose. The results of this study can be used as a planning tool and as input to the design of potential future drainage infrastructure and flood mitigation measures that are appropriate for the physical environment for both existing and future development.

1.2 PROJECT LOCATION

The Study Area is approximately 2 square miles and is located in northwest Douglas County, approximately 7 miles from downtown Carson City, Nevada. The Study Area comprises the unincorporated community of Alpine View Estates and its watershed drainage area. A vicinity map is shown in Figure 1-1.

1.3 PREVIOUS STUDY

In 2018, a FEMA Letter of Map Revision (LOMR) (KHA, 2016) became effective that included portions of Alpine View Estates. This study used both FLO-2D and HEC-RAS as hydraulic modeling tools with the hydrology being developed in HEC-HMS. The focus of these delineations were the major watercourses to the west of the Alpine View Estates community, but the FLO-2D modeling covered a large portion of the community. The grid size for the two-dimensional modeling was 20-feet with the use of the one-dimensional channel routine.

Since this LOMR was used to delineate the major watercourses near the study area, it did not focus on the internal (to the Alpine View Estates) flooding issues; and, as such, is not directly comparable to the current Alpine View Estates Drainage Master Plan (DMP). However, the LOMR was used in the DMP to gauge the relative magnitude of surface runoff that can be expected in this watershed.

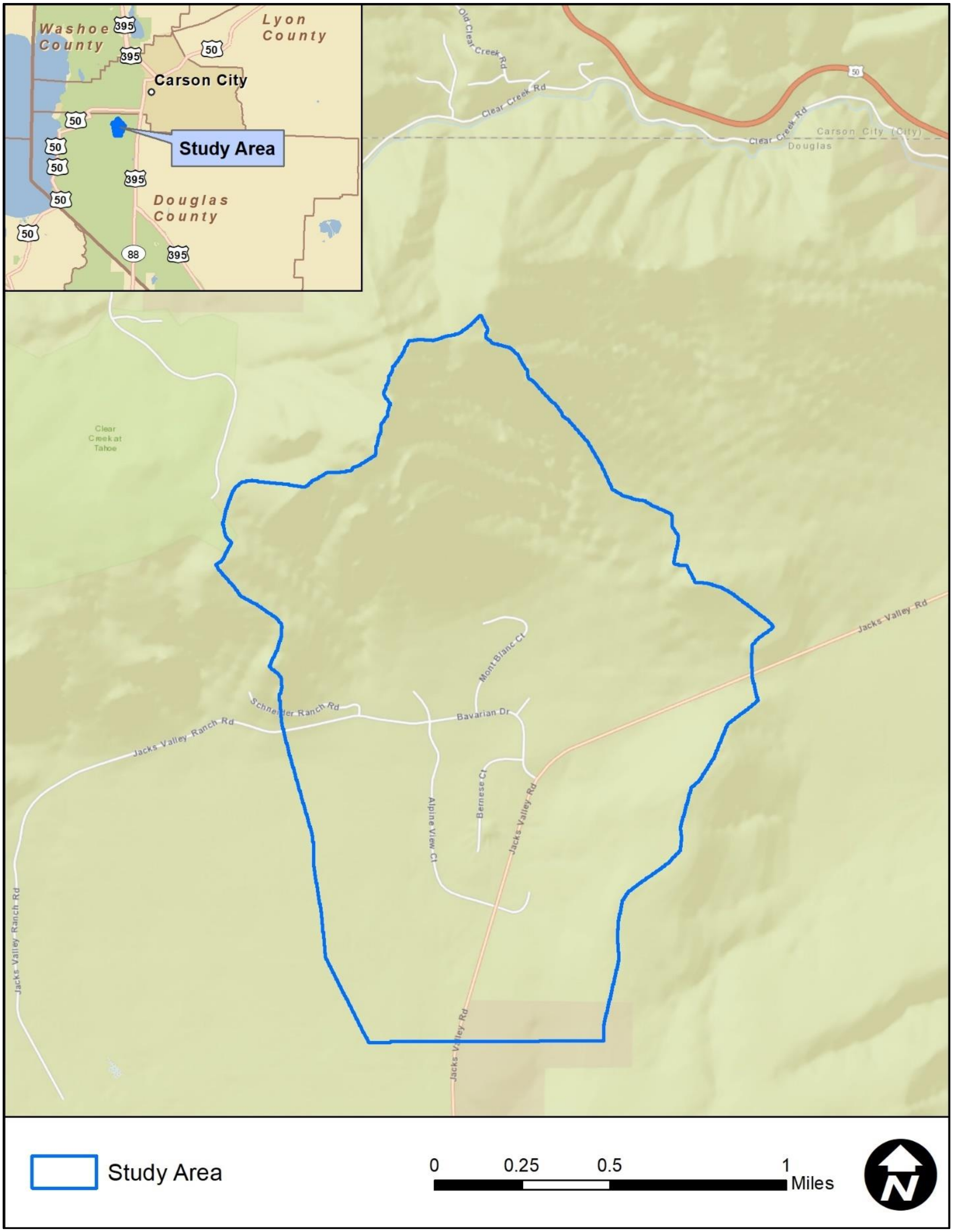

Figure 1-1. Vicinity Map

2 HYDROLOGIC AND HYDRAULIC MODELING

2.1 METHOD DESCRIPTION

All modeling, both hydrologic and hydraulic, was done using the FLO-2D Pro software[1] package, Build No. 16.06.16 with an executable dated February 28, 2017. This version has been used for multiple area drainage master studies and has functioned adequately. FLO-2D was selected for this study for the following reasons:

1) To maintain method consistency with other drainage studies in the area, such as the Johnson Lane Area Drainage Master Plan (JLADMP) (JE Fuller, 2018),
2) To streamline model development since there are many small subbasins that would require individual analysis if a lumped parameter model, such as HEC-HMS were used, and
3) FLO-2D is a combined rainfall-runoff model (i.e., both hydrologic and hydraulic processes are simulated within the model).

2.1.1 Model Domain (or Boundary)

To be consistent with item 3) above, the model boundary was selected to capture the entire watershed that drains to Alpine View Estates, so that the hydrology and hydraulics are developed entirely within FLO-2D. The model boundary is the same as the study area boundary that is shown in Figure 1-1.

2.2 MODEL DEVELOPMENT

2.2.1 Spatial Reference System

All data that was generated for this study used the horizontal control of the Nevada Coordinate System, West Zone, NAD83; while the vertical datum was the North American Vertical Datum of 1988 (NAVD 88). The units of measurement were US survey feet.

2.2.2 Grid Size

The Alpine View watershed contains many small drainage features (e.g. small roadside ditches) that need to be adequately resolved in the modeling to provide accurate results. Some of these features include small 18- to 24-inch culverts and minor roadside drainage ditches (on the order of 2-3 feet in top width). Therefore, a high-resolution, 5-foot grid-size was selected to provide the necessary detail to model these features. This grid size resulted in a relatively large model. The total number of grid elements in the model was 2,191,432.

2.2.3 Grid Element Elevations

As a part of the 3D Elevation Program[2], the USGS collected high resolution LiDAR data for a large portion of Carson City and Washoe, Storey, and Lyon Counties in Nevada through a contract with Digital Aerial Solutions, LLC (DAS) – Contract Number: G16PC00044. This data was collected at two specifications,

[1] https://www.flo-2d.com/
[2] https://www.usgs.gov/core-science-systems/ngp/3dep

Table 2-1. LiDAR flight parameters, reproduced from DAS (2018b)

Parameter	QL1	QL2
Flying Height Above Ground Level:	8,609 feet	9,072 feet
Nominal Sidelap:	60%	30%
Nominal Speed Over Ground:	155 Knots	155 Knots
Field of View:	15°	24°
Laser Rate:	220.2 kHz	206.2 kHz
Scan Rate:	65.2 Hz	49.2 Hz
Maximum Cross Track Spacing:	1.22 meters	1.62 meters
Maximum Along Track Spacing:	0.61 meters	0.81 meters
Average point Spacing:	0.50 meters	0.67 meters

QL1 and QL2. The flight parameters and point densities for both datasets are listed in Table 2-1. LiDAR collection began on September 19, 2017 and was completed on October 27, 2017 (DAS, 2018b). The original LiDAR data was collected with elevations in meters, a horizontal spatial reference of UTM Zone 11 N, Meters, NAD83, and a vertical spatial reference of NAVD 88. The DAS LiDAR reports are included in Appendix B. For this study, the entire watershed was contained within the QL1 resolution.

Since the QL1 LiDAR data was collected in meters and in a different horizontal coordinate system than the what the current DMP study used, the data was first converted to feet, the Nevada Coordinate System, West Zone, NAD83. Initially, the QL1 data was provided as multiple bare earth rasters tiles, but for this study the data was combined into a single high-resolution raster with a grid size of 1.64 feet. This high-resolution raster was resampled to a 5-foot grid raster that reflects the average grid elevations that are used in the actual FLO-2D model.

2.2.4 Precipitation Development

A total of three design storms were used in the FLO-2D modeling for the Alpine View Estates DMP. These design storms were:

- the 100-year, 24-hour storm,
- the 100-year, 6-hour storm, and
- the 25-year, 24-hour storm.

The rainfall depths were taken from the NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 1: Semiarid Southwest (Arizona, Southeast California, Nevada, New Mexico, Utah). The maximum rainfall depths within the study for each storm are:

- 4.246 inches for the 100-year, 24-hour storm,
- 2.059 inches for the 100-year, 6-hour storm, and
- 3.358 inches for the 25-year, 24-hour storm.

For each storm event, the FLO-2D RAIN.DAT file was developed with the same procedure. The general NOAA 14 rainfall rasters were downloaded from the NOAA website[3], the rasters were converted to a shapefile which was then converted to a global 5-foot raster where each cell was an area-weighted average of the rainfall depths within that cell. These global rasters were then used to assign rainfall depths for each grid of the model, and finally the rainfall depths were normalized by the maximum rainfall in each model area (using RAINARFs) to produce the RAIN.DAT file in the correct format.

2.2.5 Infiltration Development

The Green-Ampt infiltration methodology was used in this study for consistency with other, recent studies in Douglas County (KHA 2016; JE Fuller, 2018). In general, infiltration parameters are a function of the features on the ground surface (e.g., a layer of asphalt that covers the soil) or the subsurface soil type. Therefore, a detailed surface feature characterization shapefile (based on land use) was developed for this study (see Figure 2-1). This shapefile formed the basis for the surface-based infiltration parameters, while a soils shapefile from the National Resource Conservation Service (NRCS) web soil survey[4] was the basis for the soils-based infiltration parameters.

2.2.5.1 Surface-based

The infiltration parameters which are dependent on the conditions and type of the ground surface are:

- Percent impervious, and
- Initial abstraction (IA) in inches.

Table 2-2 shows the land use classification (or category), its corresponding percent impervious and IA. In addition, this table also shows the Manning's n value for each classification (discussed in Section 2.2.6). These were selected based on experience in other studies, such as the JLADMP (JEF, 2018), and aerial photograph interpretation of the study area.

The percent impervious for the Undeveloped Open Space category was set to 5% to account for the presence of any rock outcrop in the area. Similarly, general land use categories, such as Rural Residential or Single-Family Estate were assigned 2% to account for isolated areas of concrete, such as driveways or patios. The major areas of impervious surfaces (e.g., buildings and paved roads) were delineated as separate land use categories. Therefore, these general land use categories do not show a typical percent impervious that is comparable to typical land use categories used in rational method calculations since the major areas of imperviousness were delineated as a separate land use type. Finally, the off-highway vehicle (or unpaved) roads were given a percent impervious value of 25% to account for added compaction through repeated vehicle use.

[3] https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_gis.html
[4] https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

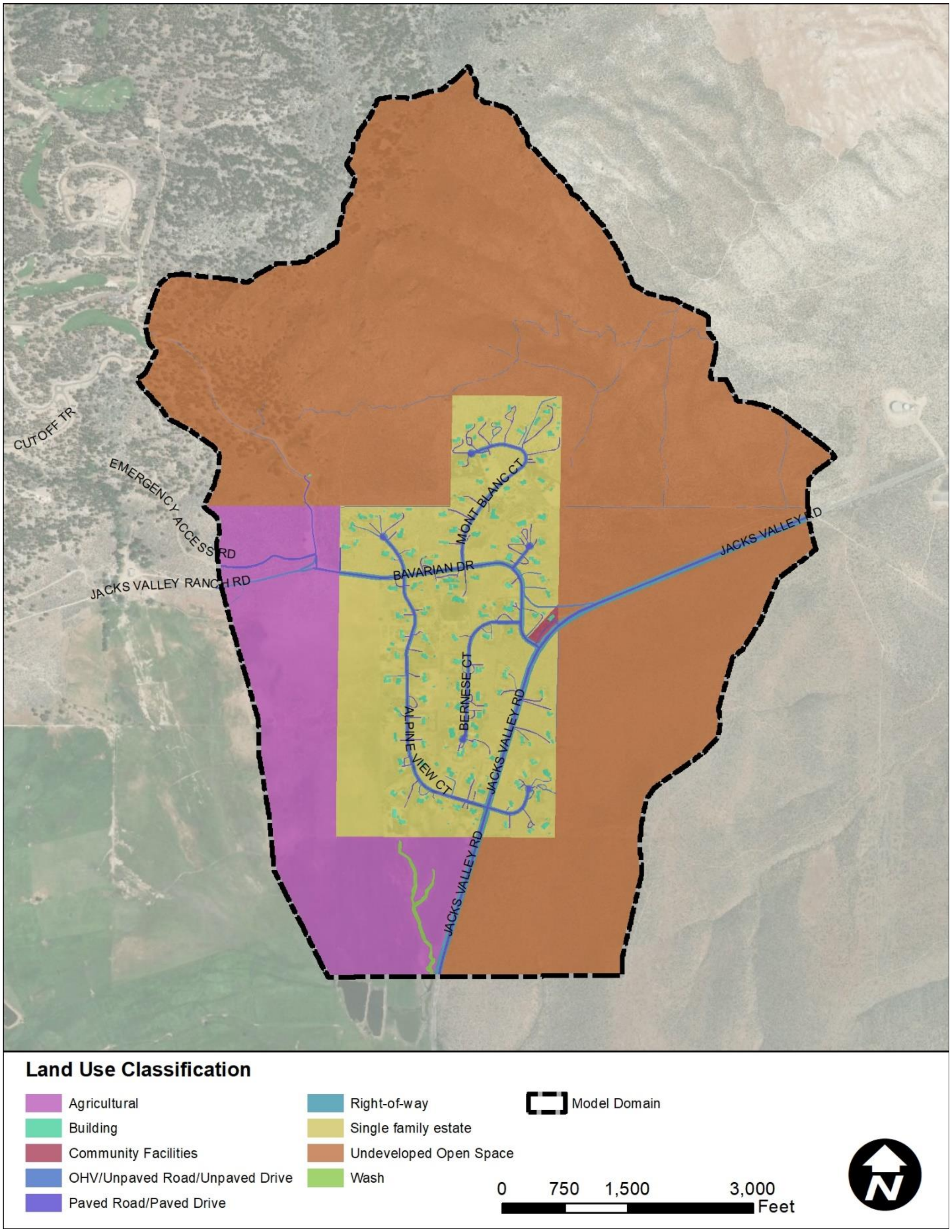

Figure 2-1. Land use classification within the model domain

Table 2-2. Land use classification with corresponding Manning's n value, percent impervious, and initial abstraction

Land Use Classification	Type	n	Percent Impervious	Initial Abstraction[1] (in)
Agricultural	Agricultural	0.060	0	0.5
Building	Building	0.050	100	0.05
Community Facilities	Community Facilities	0.040	5	0.15
OHV/Unpaved Road/Unpaved Drive	Dirt driveway, Dirt road, OHV	0.026	25	0.1
Paved Road/Paved Drive	Access road	0.026	95	0.05
Paved Road/Paved Drive	Driveway, Local Road, Secondary Road	0.020	95	0.05
Right-of-way	Right-of-way	0.040	5	0.15
Single family estate	Single family estate	0.045	2	0.15
Undeveloped Open Space	Forest and Range, Receiving area, Washoe Tribe land	0.040	5	0.25
Wash	Wash	0.030	0	0.5
1. Note that the initial abstraction used in the modeling has been reduced by 0.048 inches to recognize that the TOL (surface detention) value used by FLO-2D acts as an initial abstraction.				

2.2.5.2 Soils-based

The parameters more dependent on the subsurface soils are:

- The hydraulic conductivity at natural saturation (XKSAT), which was calculated based on the saturated hydraulic conductivity (Ks) using the formula XKSAT = Ks * 0.5, from the *Drainage Design Manual for Mohave County* (DDM) (Mohave County, 2018) and based on Bouwer (1966).
- The soil moisture deficit (DTHETA), which is the initial water content minus the saturated water content.
- The wetting front suction in inches (PSIF).
- Limiting infiltration depth in feet, which is the depth at which infiltration stops.

As mentioned previously, the soils data was downloaded from the NRCS and classified by hydrologic soil group (HSG) – a measure of how well the soil is drained by infiltration. The spatial distribution of the HSG around the study area is shown in Figure 2-2. With this classification, the saturated hydraulic conductivity (Ks) was determined based on experience through the JLADMP and guidance from the NRCS (2009). The HSG and their corresponding Ks and XKSAT values used in this study are shown in Table 2-3.

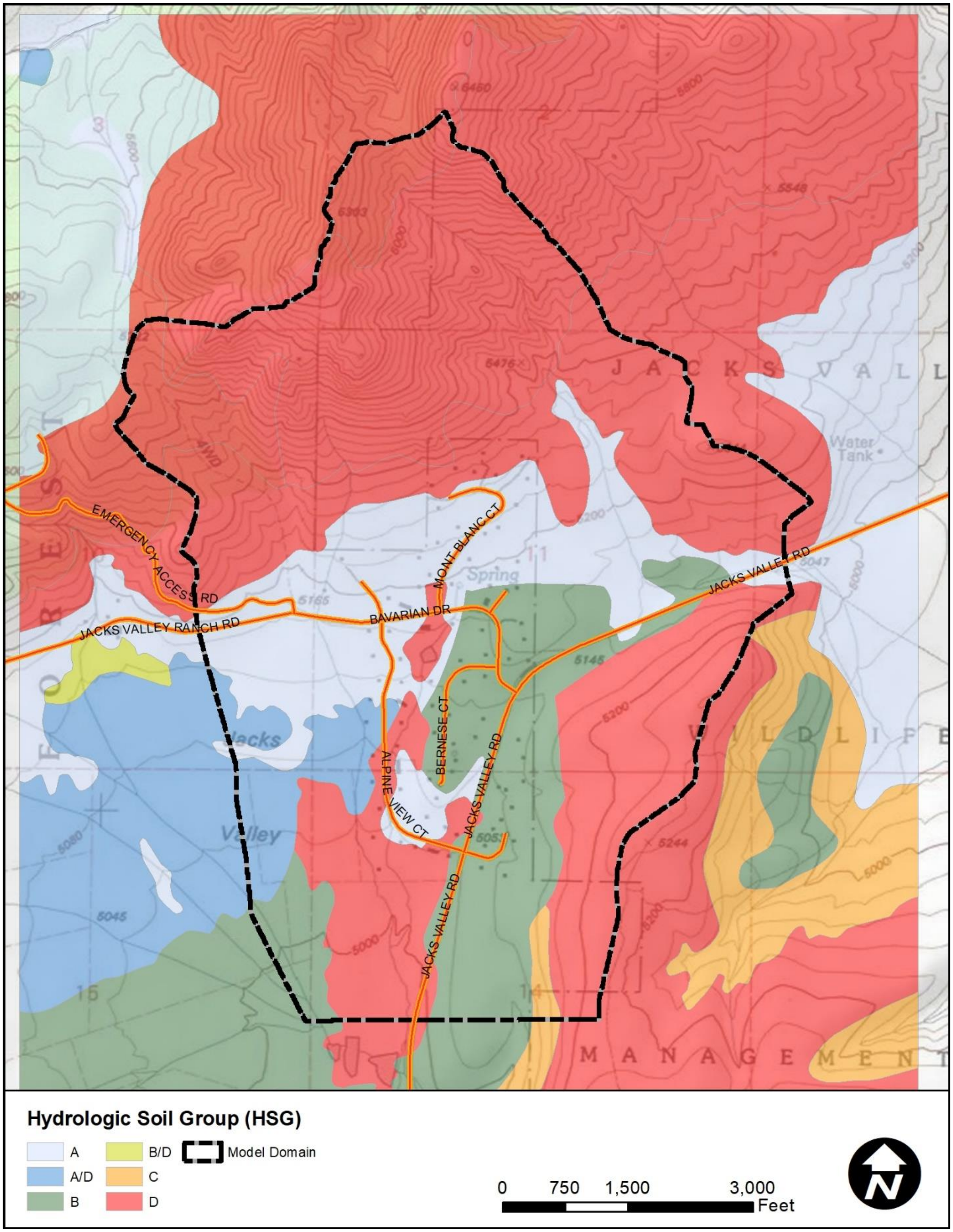

Figure 2-2. Hydrologic soil group in the vicinity of the study area

Table 2-3. Hydrologic Soil Group (HSG) and corresponding KS and XKSAT values

HSG	Ks (in/hr)	XKSAT (in/hr)
A	1.42	0.71
B	1	0.5
C	0.32	0.16
D	0.06	0.03

Both the PSIF and DTHETA values were calculated with equations from the Mohave County Drainage Design Manual[5]. PSIF was calculated with Equation 7.9, while DTHETA was calculated with Equations 7.10 or 7.11 depending on the initial moisture content of the manual. For reference, these equations are shown in Figure 2-3, while the calculated PSIF values are shown in Table 2-4. Since the DTHETA calculation is dependent on the initial moisture content (i.e., a dry or normal equation is provided), a delineation was made to define areas with dry conditions and those which are routinely irrigated. Irrigated areas include residential yards and agriculture land which appears to be irrigated in recent aerials (see Figure 2-4). Based on Equations 7.10 and 7.11 and Figure 2-4, the final DTHETA was calculated (see Figure 2-5).

Finally, the depth to a restrictive layer was determined for each soil based on the NRCS soils data. This depth was then used to define the limiting infiltration depth in FLO-2D. The depth to restrictive layer from the NRCS is shown as Figure 2-6, while the limiting infiltration depth that was used in FLO-2D is shown in Figure 2-7.

$$PSIF = 11.63103 * 0.15801^{XKSAT} \quad (7.9)$$

$$DTHETA_{Dry} = 0.36180 + 0.03953 * \log_e XKSAT \quad (7.10)$$

$$DTHETA_{Normal} = 0.28536 + 0.060058 * LOG_e(XKSAT) - 0.001009 * LOG_e(XKSAT)^2 - 0.000615 * LOG_e(XKSAT)^3 \quad (7.11)$$

Figure 2-3. PSIF and DTHETA equations, reproduced from Mohave County (2018)

5 https://www.mohavecounty.us/ContentPage.aspx?id=124&page=15&cid=392

Table 2-4. Calculated PSIF values

XKSAT (in/hr)	PSIF (in)
0.71	3.138
0.5	4.623
0.16	8.658
0.03	11.005

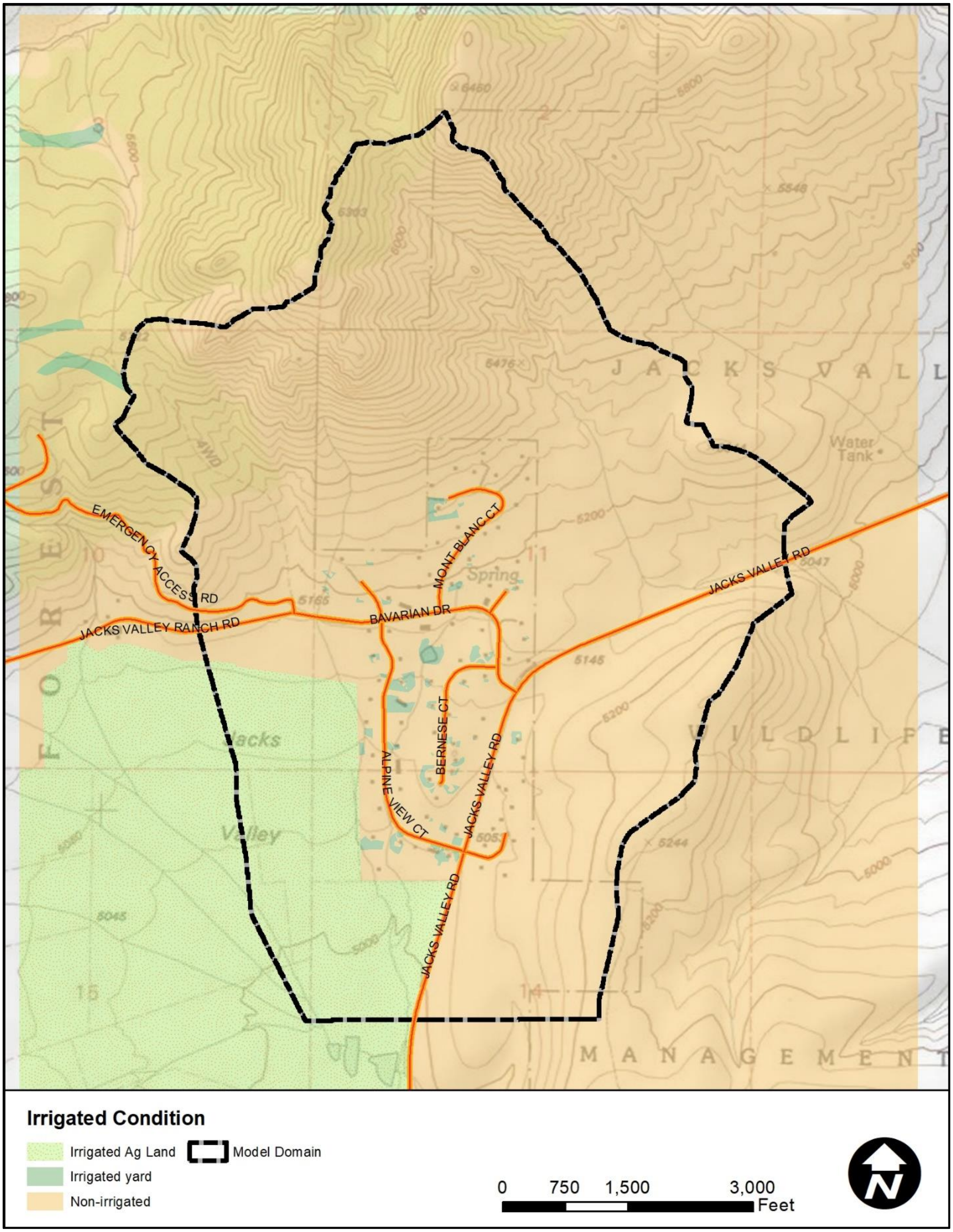

Figure 2-4. Irrigated condition of the study area

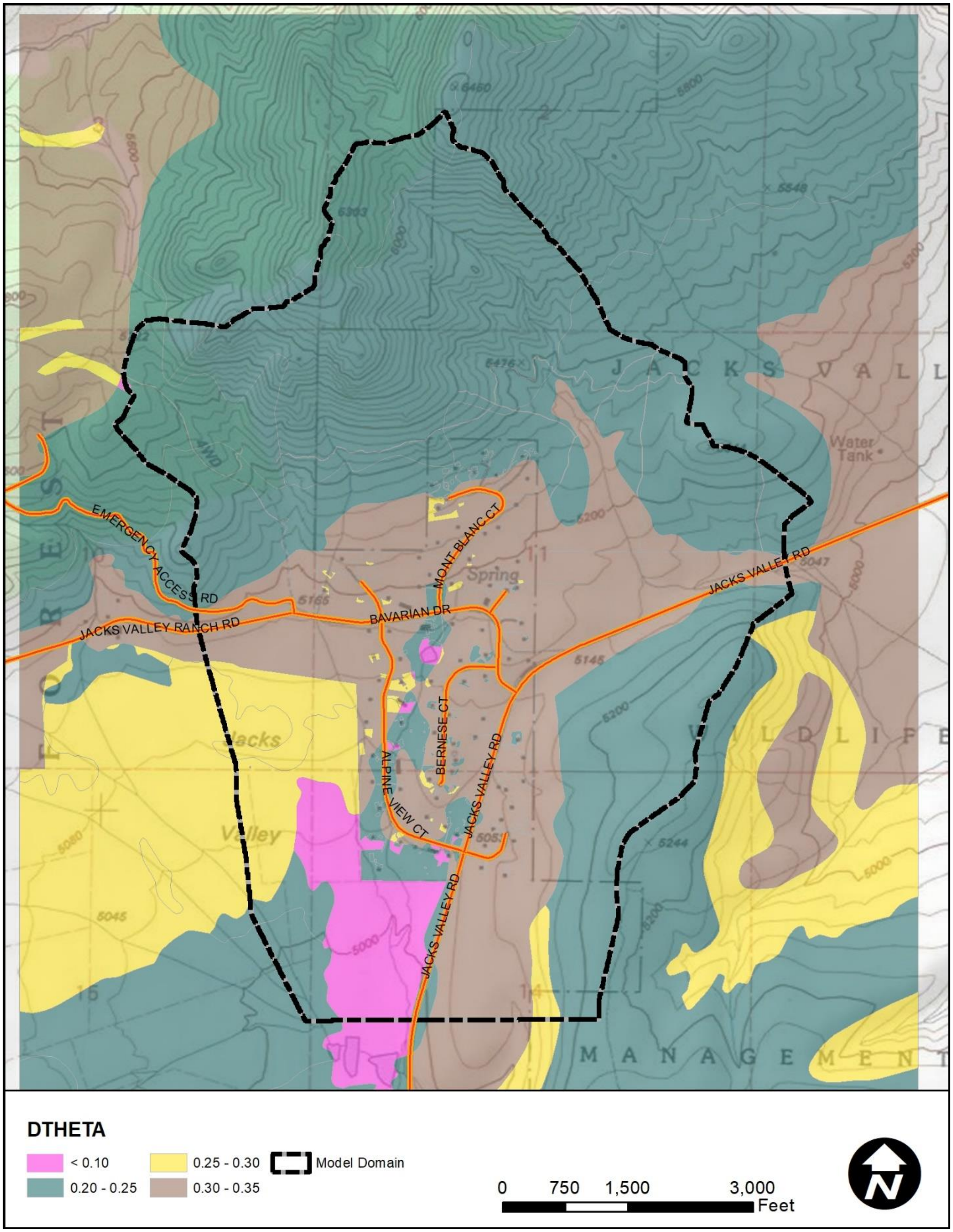

Figure 2-5. Spatial distribution of the calculated DTHETA values

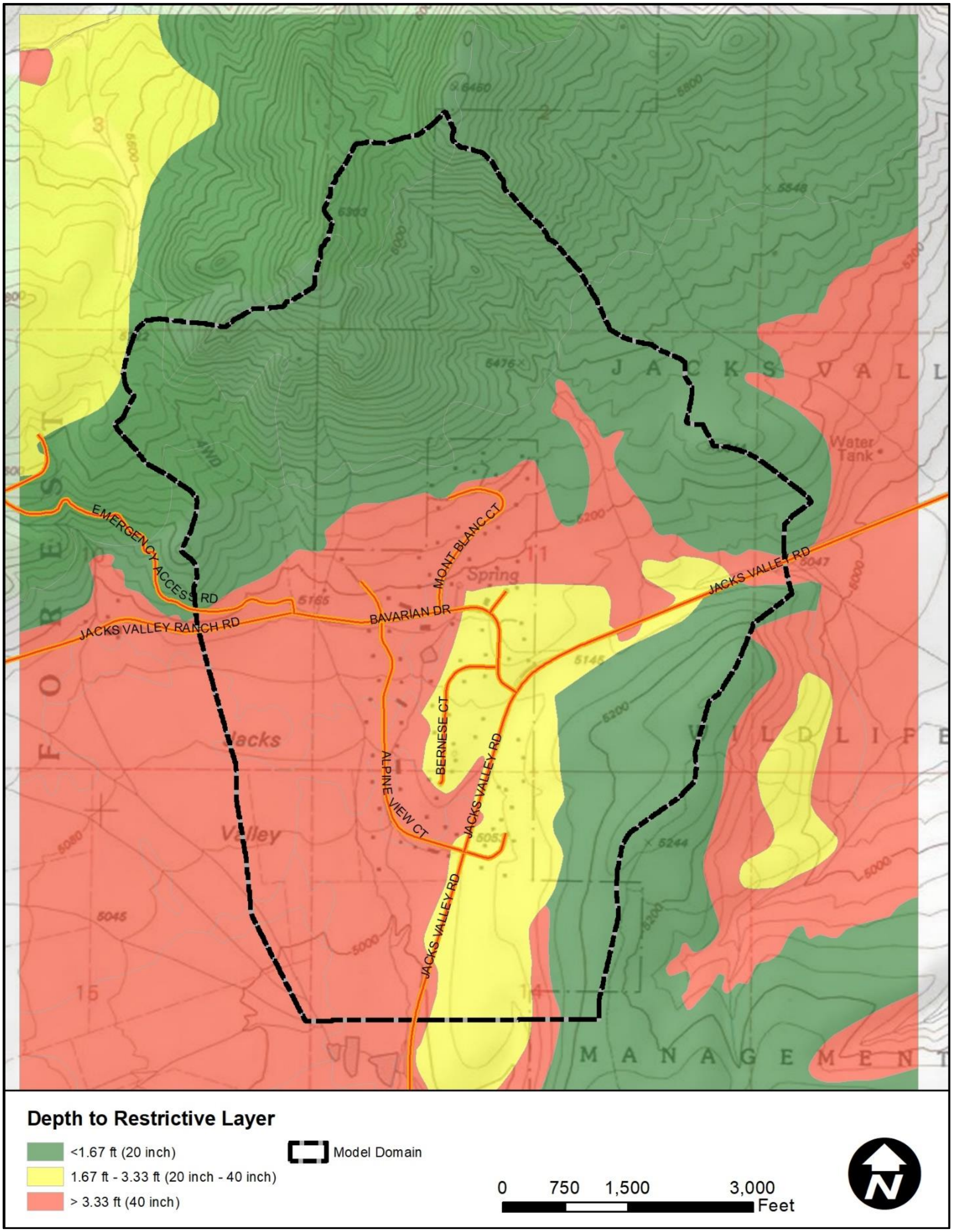

Figure 2-6. Depth to restrictive layer, per the NRCS soils data

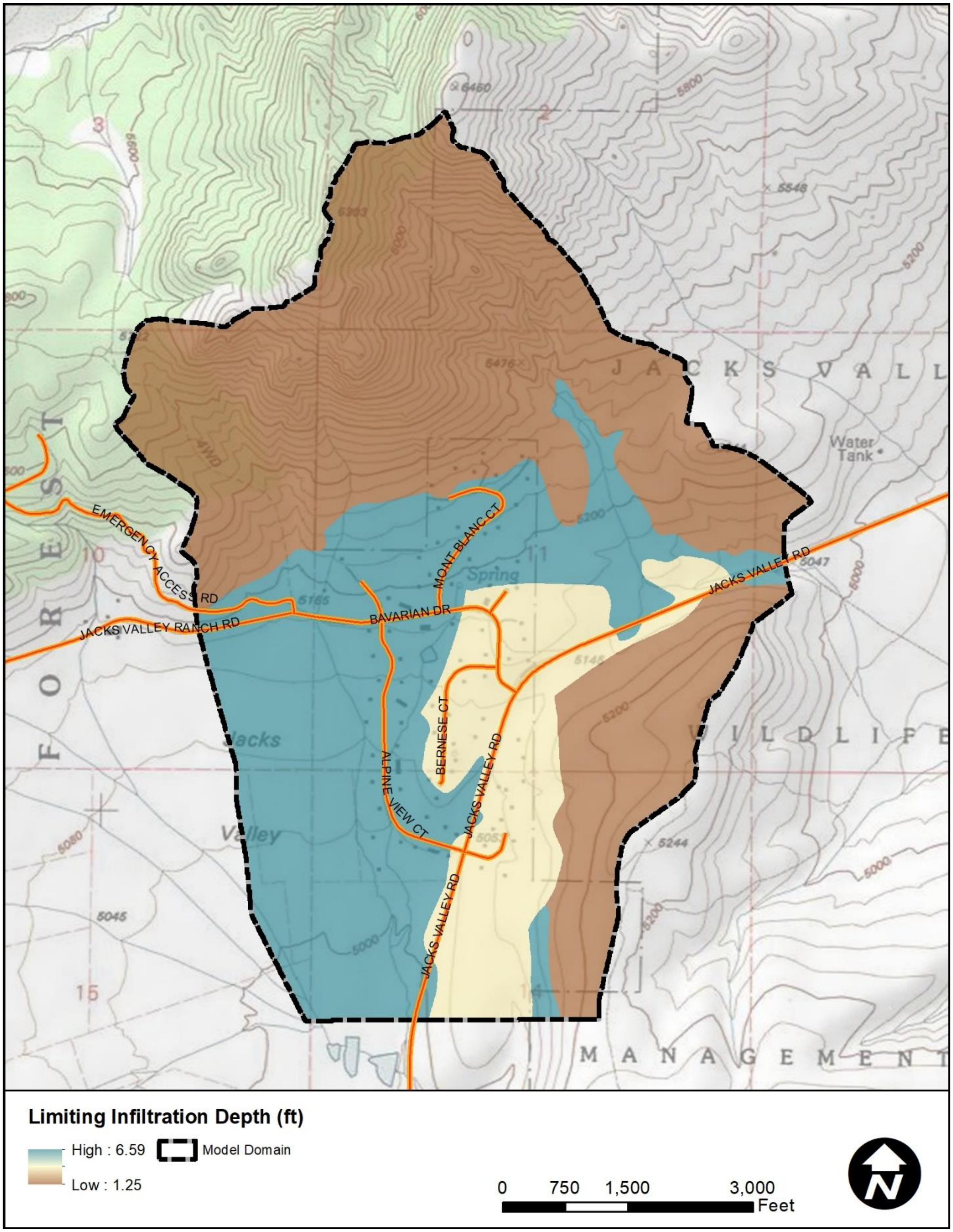

Figure 2-7. Limiting infiltration depth (in feet) used in the FLO-2D modeling

2.2.6 Grid Element Roughness

The FLO-2D model uses Manning's n value to estimate roughness on each grid. Each grid element is assigned an average n value based on the underlying surface conditions. For this study, a detailed surface feature classification was developed by refining land use data provided by Douglas County and adding more detail in areas where the delineations were too generalized. For example, major areas of pavement (parking lots and roads) and wash corridors were delineated in the modeling area since these features are major conveyances. In addition, Douglas County provided GIS data for building footprints within the study area.

Table 2-1 lists the surface classification and its corresponding Manning's n values that were used in this analysis. The spatial distribution of the surface classification was shown previously as Figure 2-1.

2.2.7 Model Control Parameters

CONT.DAT and TOLER.DAT contain numerical stability and simulation controls for the FLO-2D model. The CONT.DAT file controls simulation time, output report time interval, some numerical controls and model switches, such as infiltration and rain. The total simulation time was set to 8 hours for the 6-hour storm, while the total simulation time was set to 26 hours for the 24-hour simulations. These times were sufficient to ensure that 1) the entire storm event has occurred (i.e., all the rainfall has fallen), and 2) the floodwave has traveled through the entire study area. For this small watershed, the entire storm event was the controlling factor.

In the CONT.DAT file, the global Manning's n value adjustment factor (AMANN) and the limiting Froude number (FROUDL) are the numerical controls that were used. For this study, these controls were set to:

- AMANN = 0 (depth integrated roughness is used with the SHALLOWN parameter)
- FROUDL = 1.5
- SHALLOWN = 0.1

For the limiting Froude number, a value of 1.5 was used due to the presence of mountainous and piedmont areas where high flow velocities are possible since slopes can be greater than 20%.

The TOLER.DAT file contains the numerical tolerance settings specified for the model. These settings are: the flow exchange tolerance (TOL), percent allowed change in flow depth (DEPTOL), dynamic wave stability criteria (WAVEMAX), and Courant-Friedrich-Lewy numerical stability parameter for floodplain grid element flow exchange (COURANTFP). The settings applied were:

- TOL = 0.004 feet (the depth at which FLO-2D begins to route flow)
- DEPTOL = 0 (not used, model uses Courant number as stability criteria)
- WAVEMAX = 0 (not used, model uses Courant number as stability criteria)
- COURANTFP = 0.6 (main stability criterion used by FLO-2D)

These values have been used in similar studies, which yielded reasonable results. For this project, these values have produced good model stability and reasonable results.

2.2.8 Hydraulic Structures

Only minor culverts (e.g. < 24-inches) exist within the model domain, and these were simulated with the hydraulic structure routine within the FLO-2D software. Please see the FLO-2D Data Input Manual (FLO-2D Software, Inc., 2016) and the FLO-2D Reference Manual (FLO-2D Software, Inc., 2017) for more details on the application of this routine and its associated modeling options for this specific build of FLO-2D.

In June 2019, JEF staff conducted a site visit to assess field conditions, identified the locations of culverts, and measured culvert sizes at significant flow locations within the study area. However, not all culverts that exist within the study area were added to the model. Many of the culverts are small driveway culverts that typically can get crushed over time or filled with sediment during storm events. An example of a driveway culvert that was not modeled is shown in Figure 2-8. For those culverts that were modeled, a rating table was developed based on an inlet control spreadsheet. Since all these culverts were small, the open area was reduced to 60% to account for potential blockage from sediment deposition and the INOUTCONT variable in FLO-2D was set to 2 to account for any tailwater conditions. All culverts that were modeled as a part of this study are shown in Figure 2-9

Figure 2-8. Example of driveway culvert in the study area with minimal capacity

Figure 2-9. Modeled hydraulic structures

2.2.9 Buildings (as Flow Obstructions)

The buildings dataset (GIS shapefile) were used to create the FLO-2D ARF.DAT file, where an ARF is defined as area reduction factor. This input data file was developed with the QGIS FLO-2D Plug-in (FLO-2D Software, Inc., 2018). This procedure uses the totally blocked element routine as well as the width reduction factor (WRF) parameter. The buildings that were modeled with the ARF/WRF functionality are shown in the land use classification of Figure 2-1.

2.3 Model Results

This section presents the results of the 25-year 24-hour, 100-year 24-hour, and 100-year 6-hour storm FLO-2D results.

2.3.1 Floodplain Cross Sections

Floodplain cross-sections were developed and included in the FPXSEC.DAT file to query flow hydrographs, peak discharges, and flow volumes from the FLO-2D model at key locations. The floodplain cross-section locations are shown on Figure 2-10. Hydrograph plots at the floodplain-cross-sections for each storm event are included in Appendix A. The peak flow and volume for each floodplain cross-section are shown in Table 2-5. Since the 100-year 6-hour model had the higher peak flows, only the 100-year 6-hour and the 25-year 24-hour results are shown in this table.

2.3.2 Depth and Discharge Results

Maximum flow depth and discharge rasters were generated from the FLO-2D output data and are presented in Figure 2-11 through Figure 2-16.

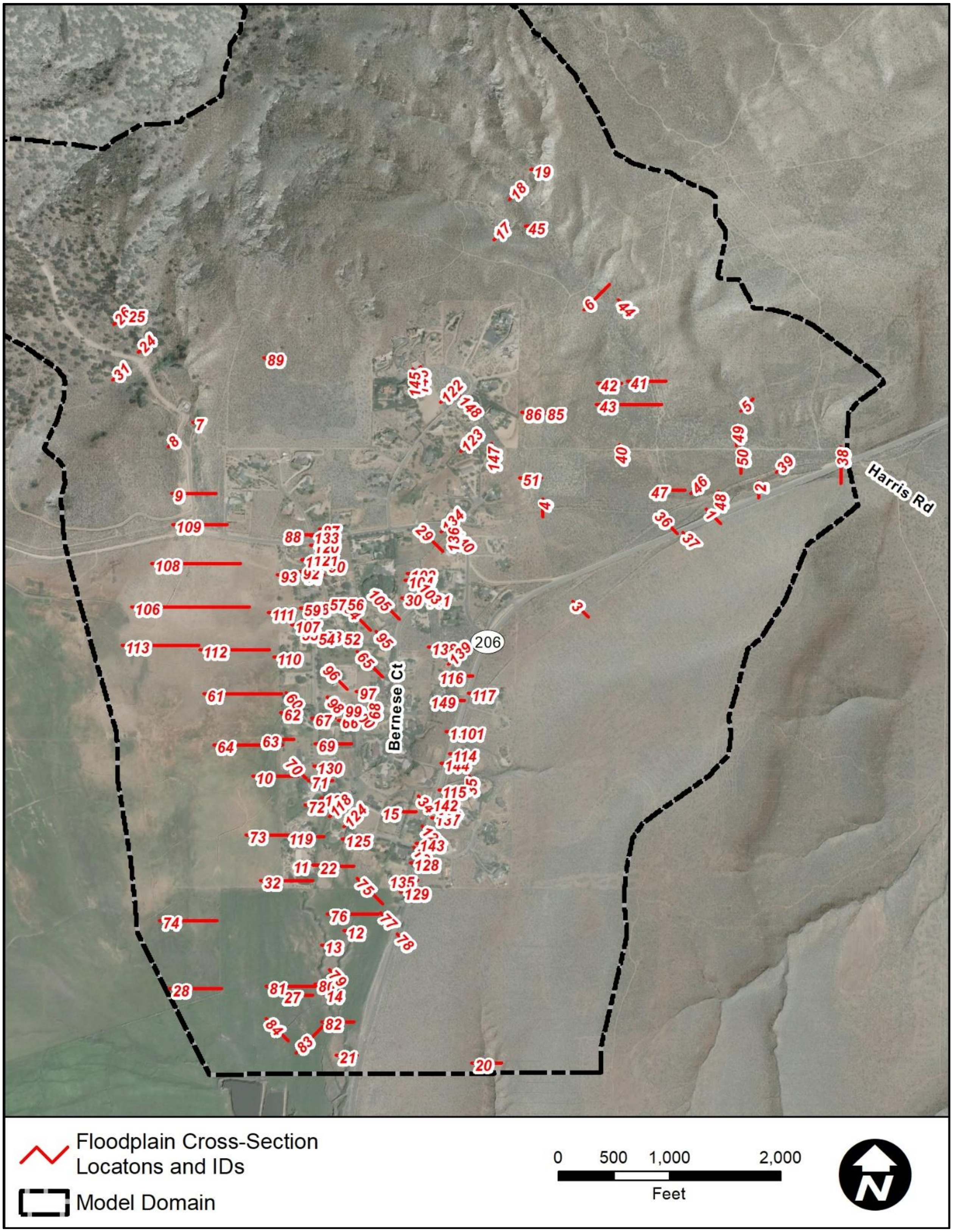

Figure 2-10. Floodplain cross-section locations and IDs

Table 2-5. Peak flow and volume results from the FLO-2D floodplain cross-sections

FPXSEC ID	100-Year, 6-Hour		100-Year, 24-Hour		25-Year, 24-Hour	
	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	CFS	AC-FT	CFS	AC-FT	CFS	AC-FT
1	89.2	3.3	59.8	3.7	41.1	2.2
2	719.9	22.9	592.8	35.9	405.6	23.0
3	5.9	0.2	4.3	0.3	3.1	0.2
4	40.6	1.2	26.7	0.9	9.9	0.4
5	89.2	2.7	73.8	5.0	54.4	3.3
6	627.1	18.7	544.4	34.6	403.1	23.8
7	281.3	8.6	268.9	17.0	200.0	12.1
8	80.8	2.5	68.3	4.6	49.5	3.2
9	400.2	12.0	363.3	22.7	268.1	15.8
10	154.9	6.9	126.0	6.5	74.1	3.2
11	31.7	2.0	23.2	2.1	6.5	1.0
12	179.5	9.0	126.4	10.2	72.1	5.8
13	58.6	2.8	42.1	2.7	18.2	1.3
14	257.6	13.7	185.8	15.6	87.4	8.5
15	10.8	0.3	7.4	0.4	3.4	0.2
16	14.2	0.3	9.1	0.2	4.4	0.1
17	139.6	4.2	135.6	8.1	103.4	5.7
18	124.2	3.7	116.1	7.3	86.4	5.1
19	274.1	8.2	248.4	16.0	184.3	11.3
20	75.5	2.0	49.9	1.7	28.2	1.0
21	280.5	15.5	207.3	18.3	100.4	10.2
22	28.9	2.4	24.5	2.5	11.5	1.4
23	61.0	1.4	32.7	1.0	16.1	0.5
24	219.3	6.7	219.2	13.3	163.3	9.4
25	120.6	3.7	127.6	7.2	96.1	5.1
26	91.2	2.8	87.9	5.5	65.3	3.9
27	104.7	6.6	83.8	7.8	42.2	4.3
28	91.2	3.6	91.5	4.3	36.5	1.8
29	55.9	2.0	43.1	1.9	14.7	1.0
30	82.1	3.0	60.9	2.7	20.7	1.3
31	62.2	1.9	54.9	3.6	40.4	2.5
32	155.7	8.2	121.9	8.6	64.4	4.5
33	88.5	3.2	68.4	4.7	45.7	2.8
34	21.2	0.6	14.5	0.5	6.1	0.2
35	92.9	2.9	60.9	4.2	41.3	2.6
36	12.3	0.4	5.3	0.2	1.4	0.1
37	66.8	2.3	45.3	2.9	29.6	1.7

FPXSEC ID	100-Year, 6-Hour		100-Year, 24-Hour		25-Year, 24-Hour	
	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	CFS	AC-FT	CFS	AC-FT	CFS	AC-FT
38	997.2	32.2	780.9	48.2	511.4	30.4
39	208.1	6.0	142.8	7.7	78.9	4.8
40	82.6	2.1	60.0	2.7	38.6	1.7
41	408.6	9.9	339.7	8.5	234.3	5.5
42	257.7	9.8	233.0	26.1	188.5	18.1
43	666.2	19.6	571.9	33.8	419.7	22.9
44	20.0	0.6	19.2	1.0	14.3	0.6
45	367.1	10.9	327.7	20.5	241.8	14.4
46	29.9	0.6	22.9	0.4	9.8	0.2
47	18.7	0.4	15.1	0.3	9.5	0.2
48	630.6	19.8	535.8	33.1	371.0	21.4
49	47.3	1.2	30.0	1.2	14.8	0.7
50	86.4	2.0	71.3	1.6	42.2	0.9
51	32.6	0.8	21.8	0.6	12.0	0.3
52	3.6	0.1	2.6	0.1	1.0	0.0
53	32.5	1.2	27.7	1.2	18.5	0.7
54	0.4	0.0	0.4	0.0	0.3	0.0
55	26.3	0.7	19.5	0.6	9.4	0.3
56	3.6	0.1	2.6	0.1	1.8	0.1
57	35.8	1.2	29.5	1.2	19.3	0.7
58	30.2	0.8	23.9	0.7	12.0	0.4
59	0.9	0.0	0.7	0.0	0.5	0.0
60	36.7	1.4	26.8	1.8	8.1	0.3
61	200.6	6.4	167.4	6.4	98.8	3.5
62	22.1	0.9	16.7	0.7	6.3	0.2
63	0.2	0.0	0.2	0.0	0.1	0.0
64	183.2	7.0	138.6	6.6	75.7	3.3
65	77.8	2.9	59.1	2.7	18.1	1.1
66	41.0	1.7	28.6	1.7	7.0	0.8
67	52.2	2.8	43.9	2.9	17.3	1.6
68	7.7	0.2	4.7	0.2	1.2	0.0
69	90.7	4.5	69.4	4.6	22.1	2.3
70	18.6	0.9	14.4	0.9	3.3	0.4
71	62.6	3.7	49.1	4.0	18.8	2.2
72	64.2	3.9	49.7	4.1	18.6	2.2
73	154.4	7.6	124.4	7.2	70.9	3.5
74	117.3	4.3	111.9	5.1	48.4	2.4
75	161.5	4.8	103.2	4.7	54.6	2.4

FPXSEC ID	100-Year, 6-Hour		100-Year, 24-Hour		25-Year, 24-Hour	
	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	CFS	AC-FT	CFS	AC-FT	CFS	AC-FT
76	230.7	10.4	149.3	11.2	77.1	6.0
77	29.7	1.5	25.7	2.5	19.8	1.5
78	13.1	0.5	10.0	0.5	5.8	0.4
79	201.9	10.3	143.0	12.3	83.7	7.0
80	257.9	13.8	186.1	15.6	87.6	8.5
81	106.6	6.8	85.4	8.0	43.3	4.4
82	276.5	15.2	203.5	17.9	99.3	10.0
83	92.6	6.1	75.5	6.8	38.7	3.6
84	12.4	1.0	9.5	2.0	4.4	1.3
85	54.9	1.6	44.3	2.6	32.5	1.7
86	30.1	0.7	22.1	0.6	14.0	0.3
87	45.2	1.3	37.3	1.3	23.5	0.8
88	31.0	0.8	23.0	0.7	14.4	0.4
89	86.9	2.5	79.2	4.7	63.1	3.3
90	1.1	0.0	1.1	0.0	0.6	0.0
91	46.5	1.4	37.4	1.4	22.9	0.8
92	15.9	0.5	13.0	0.5	8.2	0.3
93	11.4	0.3	8.7	0.2	3.7	0.1
94	3.4	0.1	2.8	0.4	1.8	0.1
95	79.5	2.9	60.2	2.6	19.0	1.2
96	57.6	2.4	44.8	2.3	14.3	1.0
97	17.2	0.7	11.9	0.7	3.1	0.3
98	39.3	1.8	31.4	1.8	10.6	0.8
99	19.8	0.8	14.5	0.8	3.9	0.3
100	20.3	0.9	13.7	0.9	3.2	0.4
101	46.3	1.3	33.0	1.1	18.0	0.6
102	78.2	2.8	58.2	2.6	19.8	1.3
103	30.5	1.2	22.5	1.1	8.4	0.6
104	48.1	1.6	35.6	1.4	11.3	0.7
105	81.3	2.9	60.6	2.6	19.5	1.2
106	467.0	13.2	410.2	18.3	280.8	11.4
107	4.1	0.2	3.4	0.1	2.0	0.1
108	474.2	13.4	425.7	21.6	296.9	14.2
109	453.0	13.3	408.1	23.5	297.5	15.9
110	13.6	0.5	10.3	0.4	3.0	0.1
111	10.5	0.3	7.7	0.3	2.6	0.1
112	204.9	6.3	174.2	6.6	114.3	3.9
113	243.9	6.6	223.9	8.9	150.9	5.4

FPXSEC ID	100-Year, 6-Hour		100-Year, 24-Hour		25-Year, 24-Hour	
	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	CFS	AC-FT	CFS	AC-FT	CFS	AC-FT
114	48.2	1.3	34.5	1.2	0.2	0.0
115	88.7	3.2	68.4	4.7	18.6	0.6
116	7.3	0.1	4.3	0.1	45.7	2.8
117	42.0	1.1	29.4	1.0	2.0	0.1
118	45.1	3.1	38.0	3.4	17.0	0.5
119	24.9	1.5	18.0	1.7	16.4	2.0
120	41.5	1.3	35.8	1.4	6.0	1.0
121	52.3	1.6	42.0	1.5	25.0	0.9
122	9.5	0.3	7.2	0.3	25.5	0.9
123	19.3	0.4	13.7	0.4	6.1	0.2
124	19.6	1.7	18.2	1.8	9.2	0.2
125	13.1	1.3	12.2	1.5	10.3	1.1
126	137.0	4.4	105.4	4.1	8.1	1.0
127	146.4	4.4	99.1	4.4	68.4	2.5
128	58.3	2.4	49.0	3.8	59.6	2.5
129	30.9	1.8	28.6	3.4	34.9	2.3
130	56.9	3.5	46.3	3.8	24.8	2.2
131	68.2	2.0	54.6	2.0	18.5	2.1
132	61.6	3.8	49.0	4.0	33.6	1.2
133	28.8	0.7	22.0	0.7	18.4	2.2
134	17.2	0.4	11.1	0.3	14.2	0.4
135	41.8	2.4	38.5	4.0	2.8	0.1
136	18.1	0.8	16.2	0.9	33.5	2.7
137	147.6	4.6	100.7	5.7	11.8	0.6
138	3.8	0.1	2.8	0.1	61.8	3.3
139	0.8	0.0	0.4	0.0	1.5	0.0
140	34.5	0.9	28.0	0.8	0.2	0.0
141	0.4	0.0	0.3	0.0	8.4	0.2
142	1.2	0.0	0.6	0.0	0.1	0.0
143	24.6	0.9	14.0	2.1	0.4	0.0
144	17.0	0.4	10.1	0.3	6.5	1.2
145	21.1	0.6	17.4	1.1	4.5	0.1
146	35.8	1.1	29.6	1.7	12.4	0.8
147	0.5	0.0	0.3	0.0	21.4	1.2
148	17.4	0.6	15.3	1.0	0.2	0.0
149	8.6	0.2	5.5	0.1	12.6	0.6

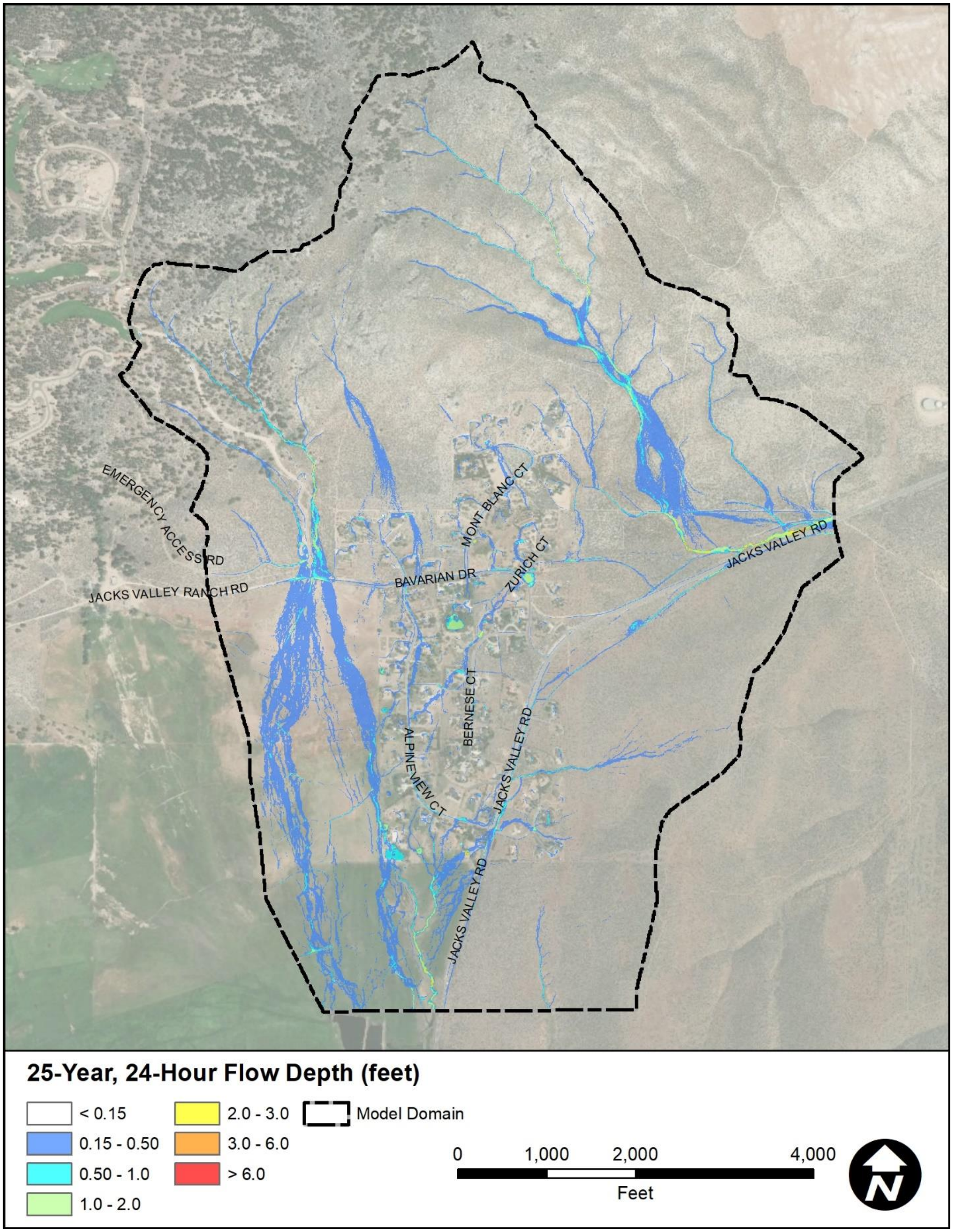

Figure 2-11. FLO-2D 25-Year 24-Hour flow depth results

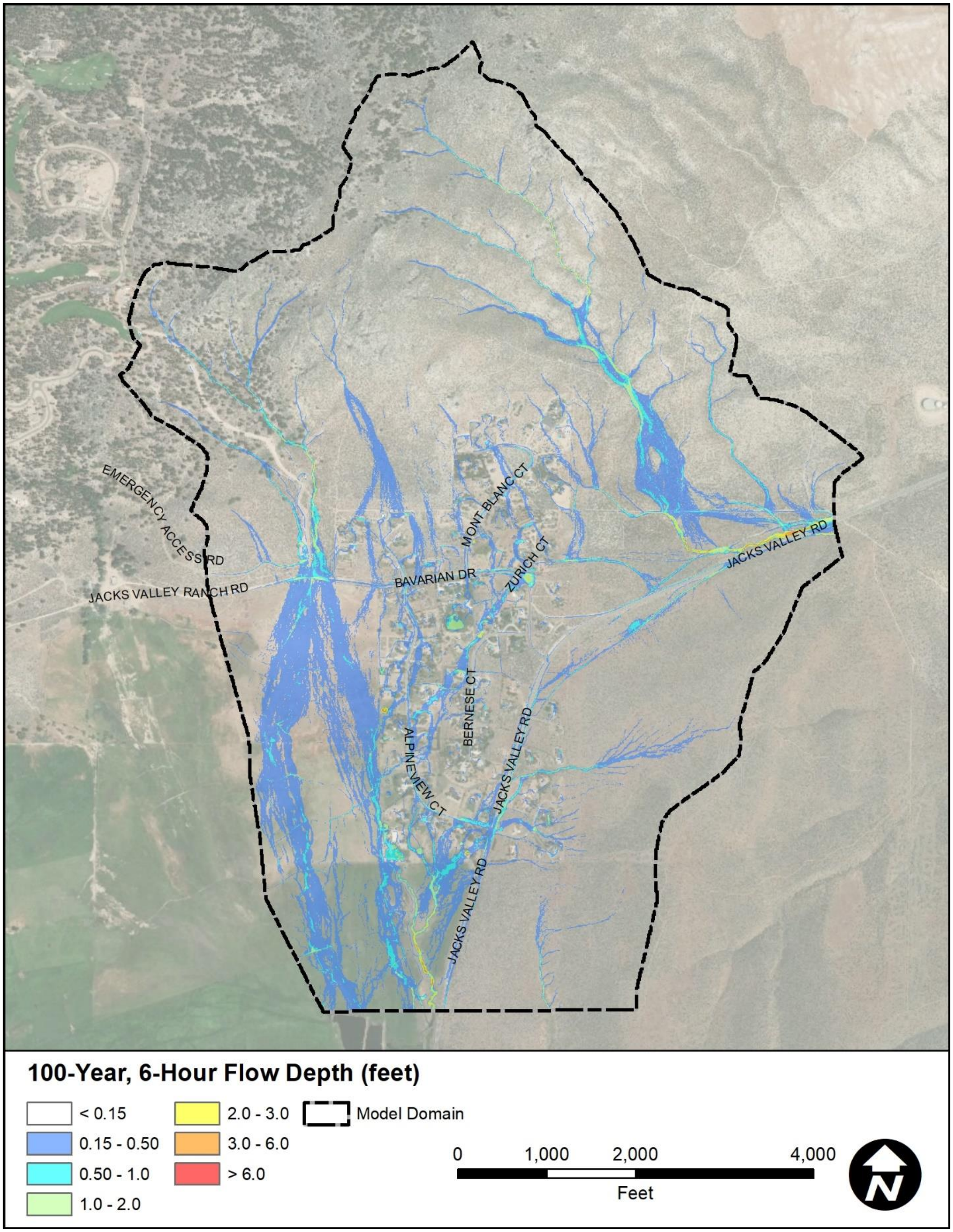

Figure 2-12. FLO-2D 100-Year 6-Hour flow depth results

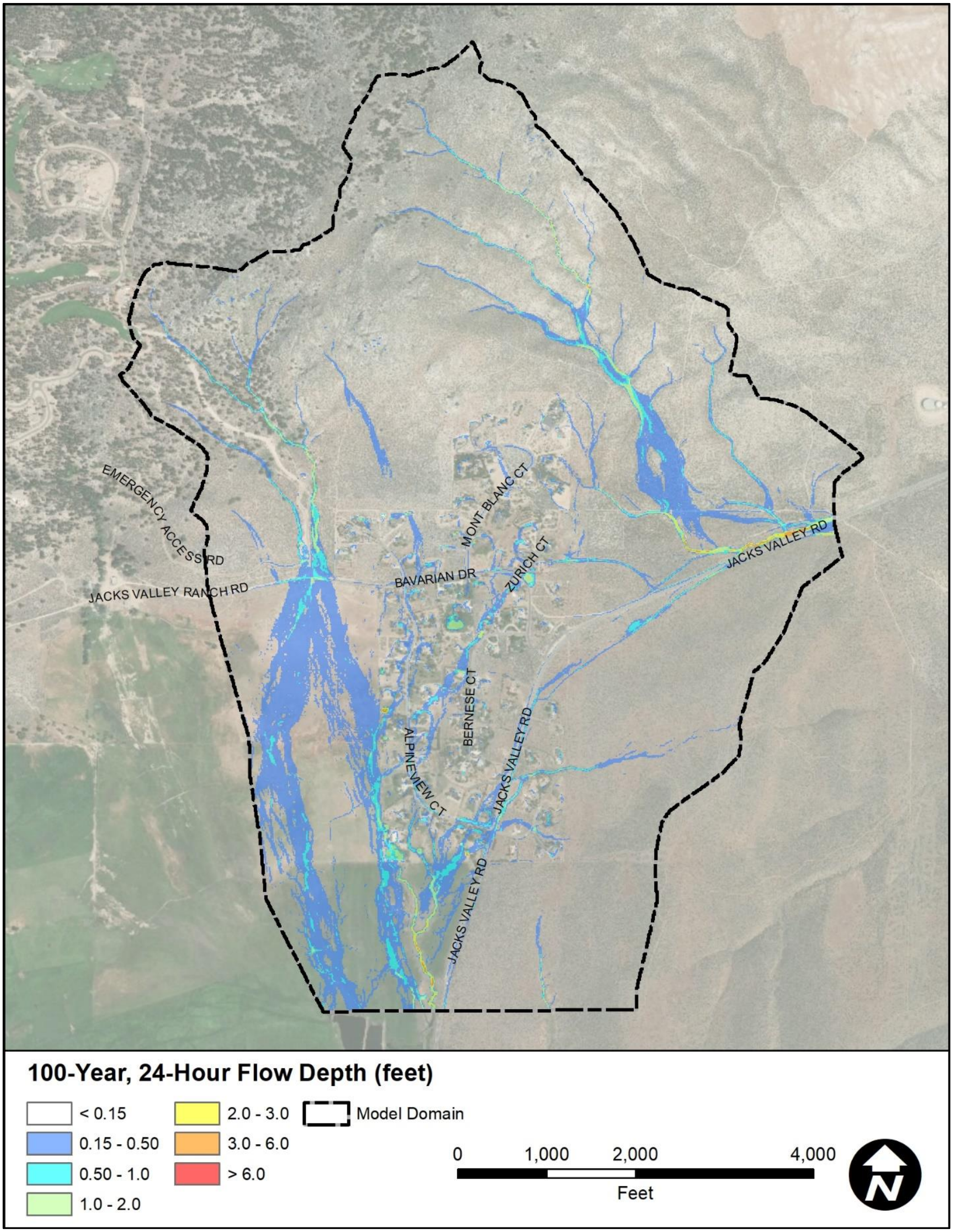

Figure 2-13. FLO-2D 100-Year 24-Hour flow depth results

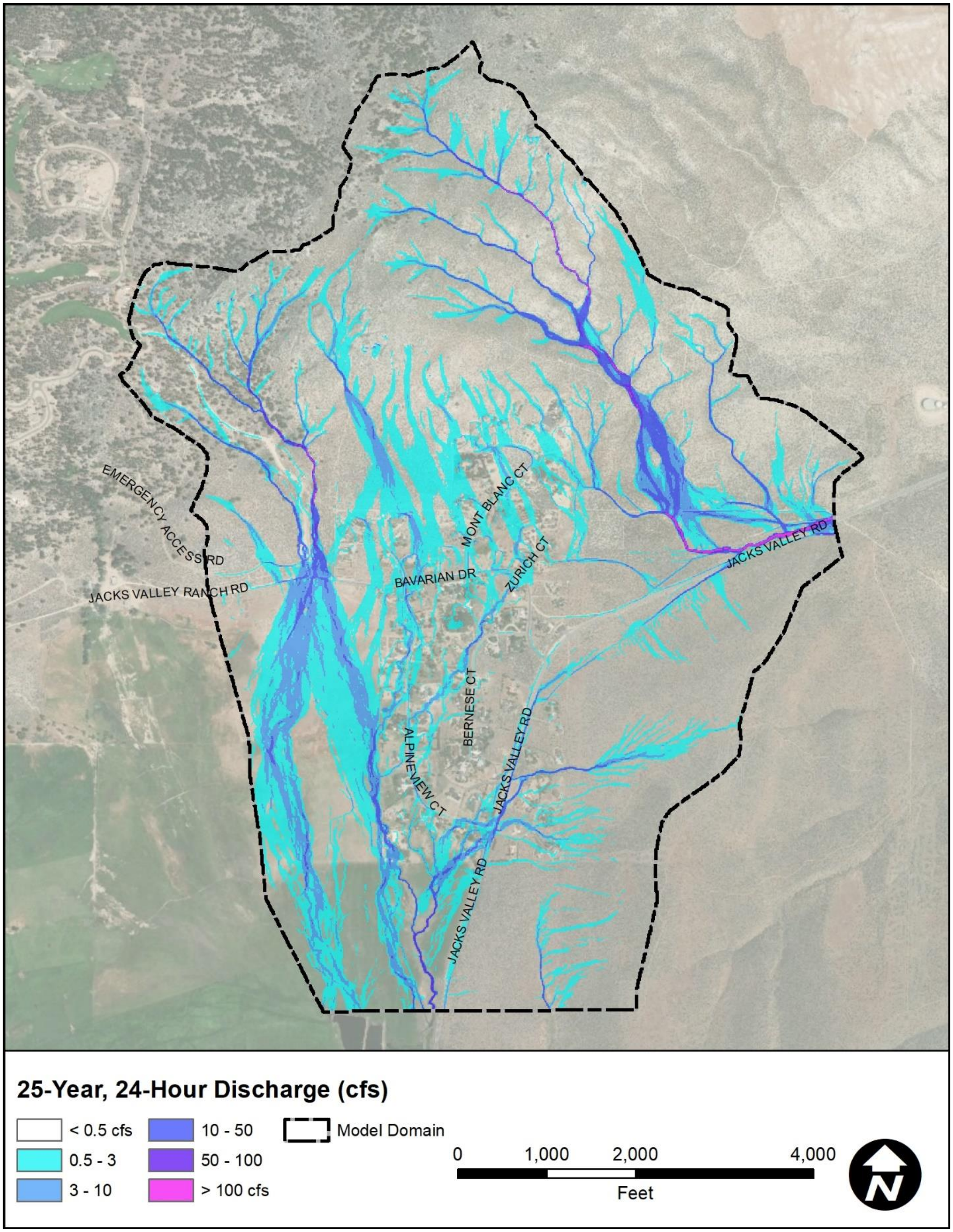

Figure 2-14. FLO-2D 25-Year 24-Hour discharge results

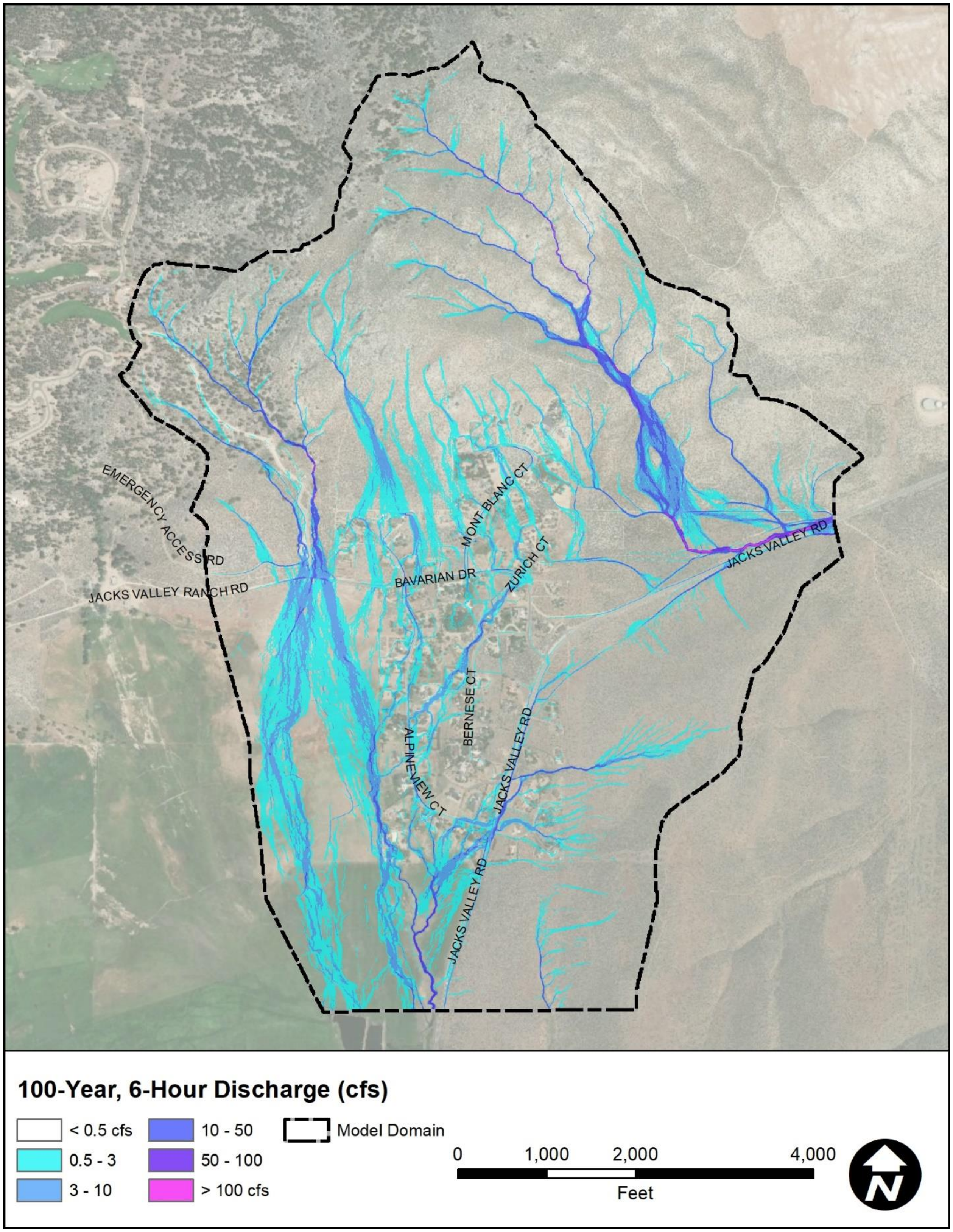

Figure 2-15. FLO-2D 100-Year 6-Hour discharge results

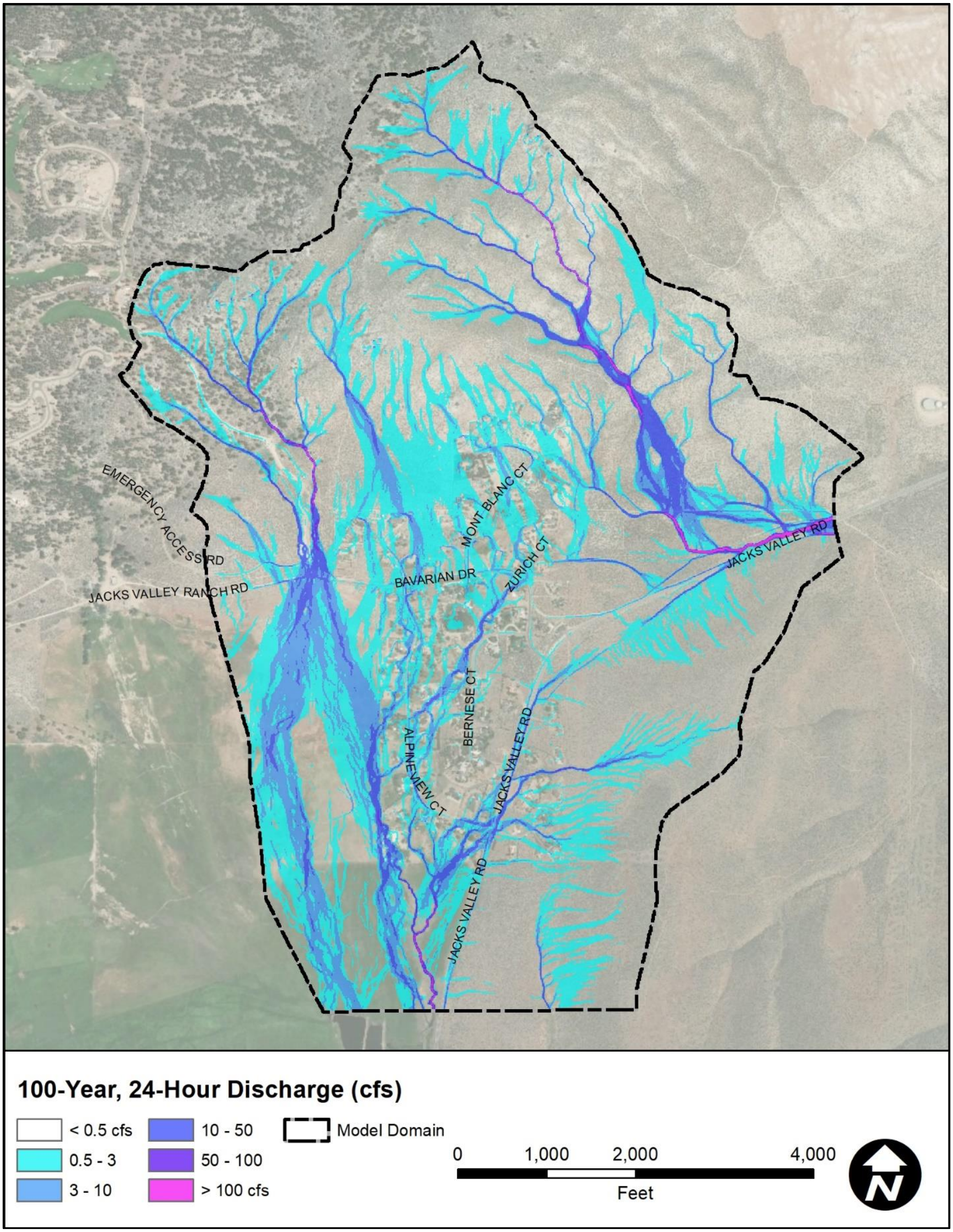

Figure 2-16. FLO-2D 100-Year 24-Hour discharge results

2.4 VERIFICATION OF RESULTS

2.4.1 Effective FEMA Study

As an assessment of reasonability, the overall infiltration percentages in the FLO-2D models were compared with those calculated in the effective FEMA study (KHA, 2016). In general, the 2016 study showed about 70-95% infiltrated volume (or rainfall loss) for the subbasins within the study area in the 100-year HEC-HMS models. A comparison of the 100-year FLO-2D model and HEC-HMS infiltration percentages is shown in Table 2-6, while the spatial locations of the FLO-2D model domain relative to the KHA HEC-HMS subbasins is shown in Figure 2-17. Since the modeling domains do not have the same boundaries, the 100-year FLO-2D model infiltration values of 66.9% (100-year 6-hour) and 77.1% (100-year 24-hour) were considered reasonable but slightly conservative, which is acceptable when planning flood control mitigation structures.

Table 2-6. Infiltration comparison between KHA FEMA study and current FLO-2D modeling

HEC-HMS Basin ID	Area (Acres)	Percent Infiltration (%)
B300	200.7	96.2%
B350	97.1	83.3%
B380	128.0	82.5%
B390	160.3	82.4%
B370	29.9	67.1%
B290	133.2	92.4%
B340	29.3	74.2%
B310	62.9	89.1%
B330	13.9	83.5%
B360	57.6	70.0%
Weighted Average (HEC-HMS)		**85.9%**
FLO-2D (100Y6H)		**66.9%**
FLO-2D (100Y24H)		**77.1%**

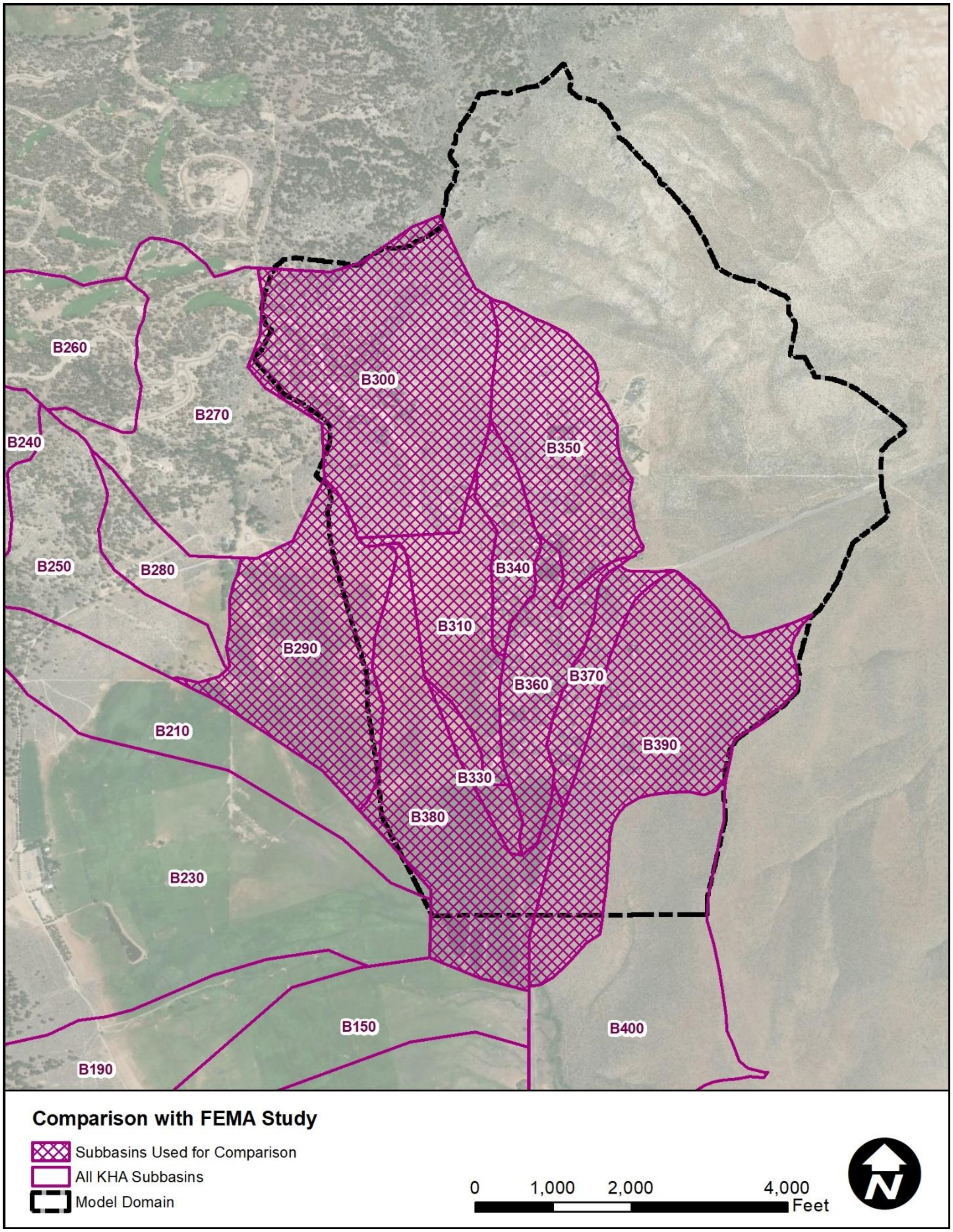

Figure 2-17. HEC-HMS subbasins used for infiltration verification

2.4.2 100-year USGS Regression Equation

As another verification of model results, the 100-year FLO-2D results (both 6- and 24-hour) were compared with the 100-year USGS regression equation for the Eastern Sierras Region 5 (USGS, 1997). This comparison is shown in Table 2-7 and Figure 2-18, while the basin locations that were used for the comparison are shown in Figure 2-19. These basin locations were chosen such that flow remained confined thus avoiding reduced peak discharges as flow expanded over distributary surfaces. This allows for a more representative comparison with the USGS regression equation. Note that all basins have drainage areas less than 1 square mile.

The 100-year 6-hour (100Y6H) results control (i.e., are higher) when compared with the 100-year 24-hour (100Y24H) results, with the 100-year 6-hour results falling below the envelope curve and the 100-year 24-hour results generally following the 100-year peak discharge line for the study area (which includes USGS Regression Regions 2-12, not just Region 5). In general, this comparison indicates that the 100-year FLO-2D results are conservative (i.e., higher) but not unreasonable. However, it should be noted that with such small drainage areas short duration high intensity events which can overwhelm the natural infiltration rate producing very high peak flows and runoff rates. Additionally, only one gaged site with a watershed area less than 1 square mile was used to develop the regression equation for Region 5, and it falls outside the cloud of common values (see Figure 27 in USGS, 1997). This means that small drainage areas can exhibit wide variability in peak flows, as evidenced by the one data point that is above the envelope curve in Figure 2-18.

Since the 100-year 6-hour storm controlled, this storm will be used to size the mitigation alternatives. This result is not surprising because shorter duration storms generally control for small drainage areas.

Table 2-7. Comparison with 100-year USGS regression equation

Basin ID	FPXSEC ID	Basin Area (sq. miles)	FLO-2D 100Y6H Peak Flow (cfs)	FLO-2D 10024H Peak Flow (cfs)	Regression Peak Flow (cfs)
110	9	0.196	400	363	77
120	89	0.051	87	78	25
210	17	0.061	140	136	28
220	18	0.058	124	116	27
230	19	0.131	274	270	50
210, 220, 230, 240	38	0.724	997	781	231
300	20	0.078	75	45	43

2.4.3 Repetitive Flooding Areas

Douglas County identified a series of parcels within the subdivision that have experienced repetitive flooding issues. Figure 2-20 shows the identified parcels with the existing conditions 25-year 24-hour FLO-2D depth results which confirm potential flooding issues within the identified parcels.

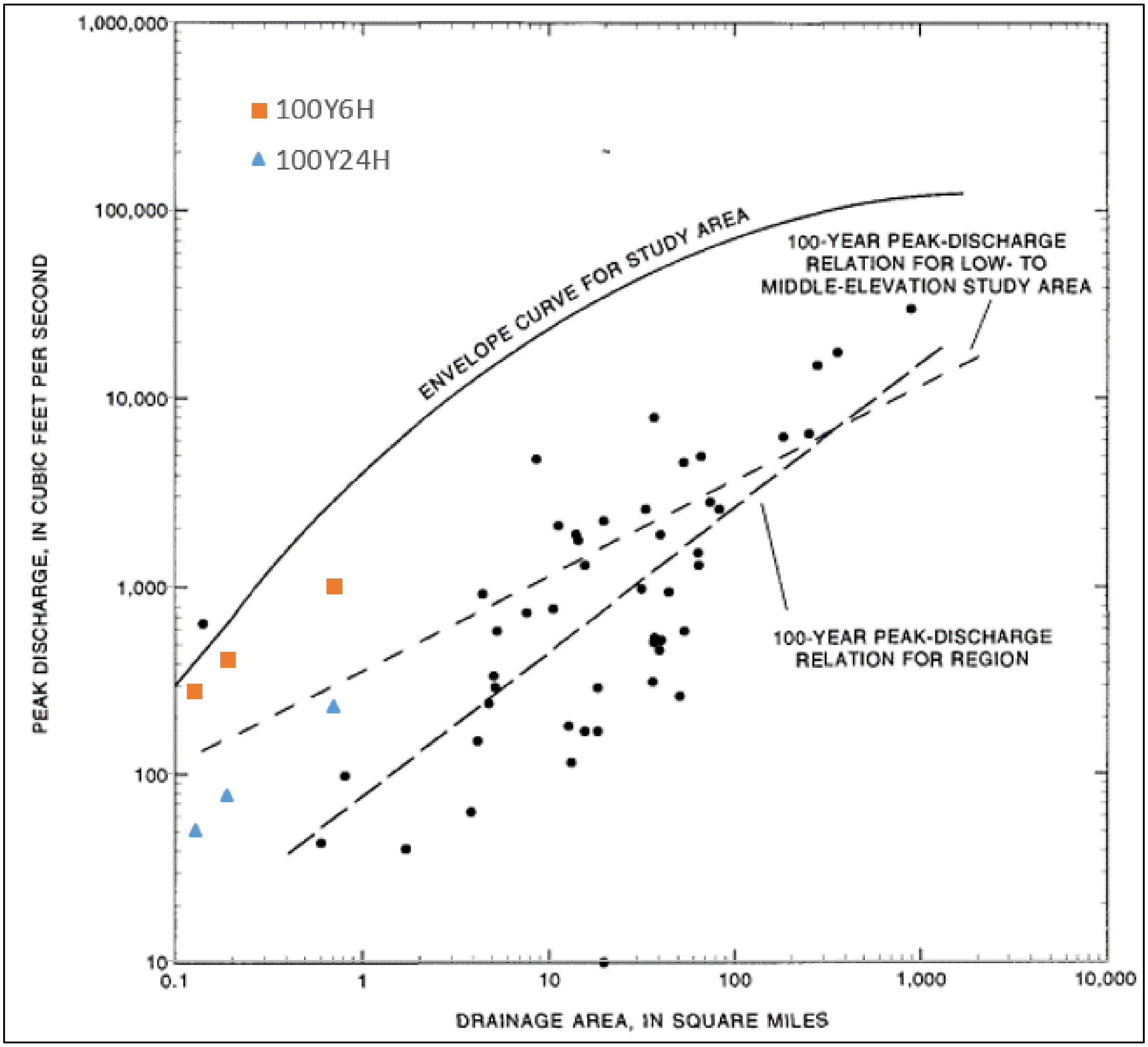

Figure 2-18. Comparison of FLO-2D results with the relations between 100-year peak discharge and drainage area and plot of maximum peak discharge of record and drainage area for gaged sites in the Eastern Sierras Region 5, adapted from USGS (1997).

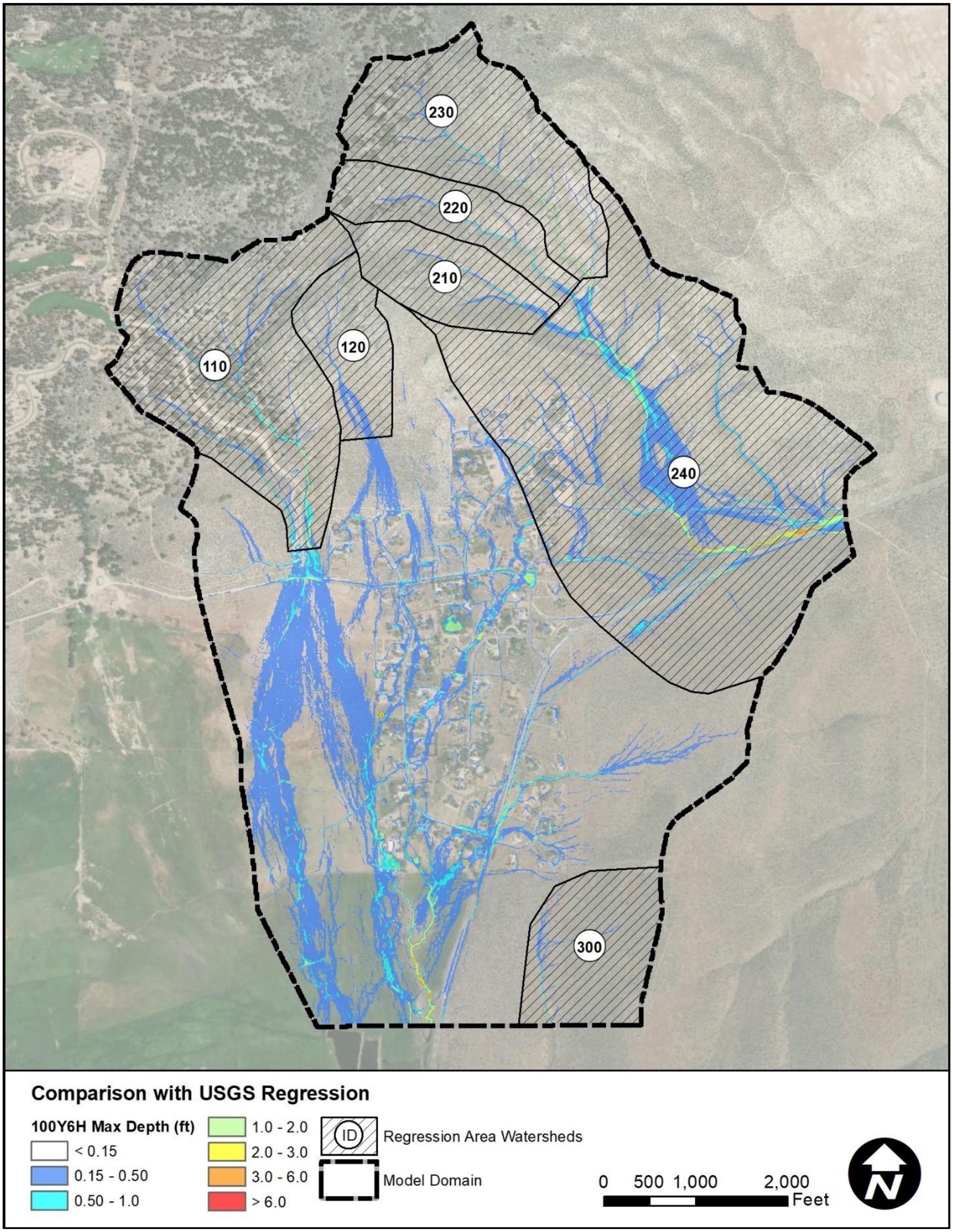

Figure 2-19. Basin locations used in comparison with 100-year USGS regression equation

Figure 2-20. Parcels with repetitive flooding issues

3 MITIGATION ALTERNATIVE CONCEPTS

The FLO-2D analyses indicate the 100-year, 6-hour event is the controlling storm throughout the study area (see Table 2-5), thus was the storm event used for the mitigation alternative concept analyses. In addition, the 25-year 24-hour storm was also examined since this is the regulatory storm for Douglas County.

Three primary areas of concert that have experienced repeated flooding issues (Figure 3-2) were identified by Douglas County:

- Properties downstream of Bavarian Drive and Zurich Court (Area 1)
- Properties along Alpine View Court between Bavarian Drive and Jacks Valley Road (Area 2)
- The cul-de-sac on Bernese Court (Area 3)

The proposed alternatives for this study consist of new culverts, improvements to existing drainage ditches and channels, and the development of a small basin. The locations of the structures with their associated ID are shown in Figure 3-1.

Figure 3-1. Proposed mitigation structures

3.1 AREA 1

The FLO-2D results indicate significant backwater at the northeast intersection of Bavarian Drive and Zurich Court with flow overtopping Bavarian Drive and flowing southwest through the subdivision. This general flowpath is also reflected in the effective FEMA 0.2% Annual Chance Flood Hazard Zone (or Shaded X) (see Figure 3-3). A series of drainage easement channels currently extend from Bavarian Drive to Jack's Valley Road (Figure 3-4) that could be improved to conveying flows through the subdivision without resulting is adverse flooding. Improvements to the drainage easement channels combined with culvert improvements were investigated as mitigation alternatives for Area 1.

Figure 3-2. Primary areas of concern

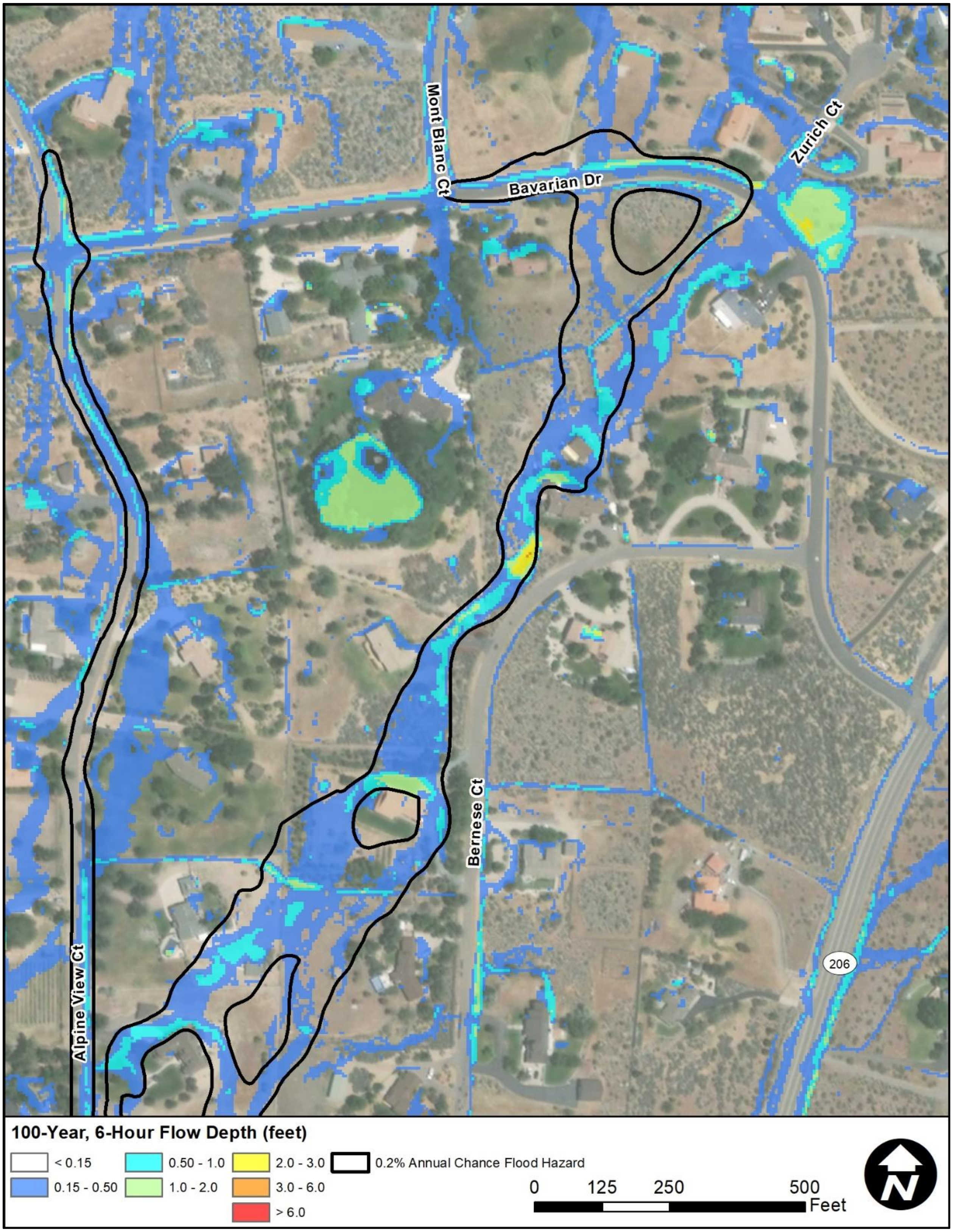

Figure 3-3. 100-Year 6-Hour FLO-2D results compared to effective FEMA flood zones

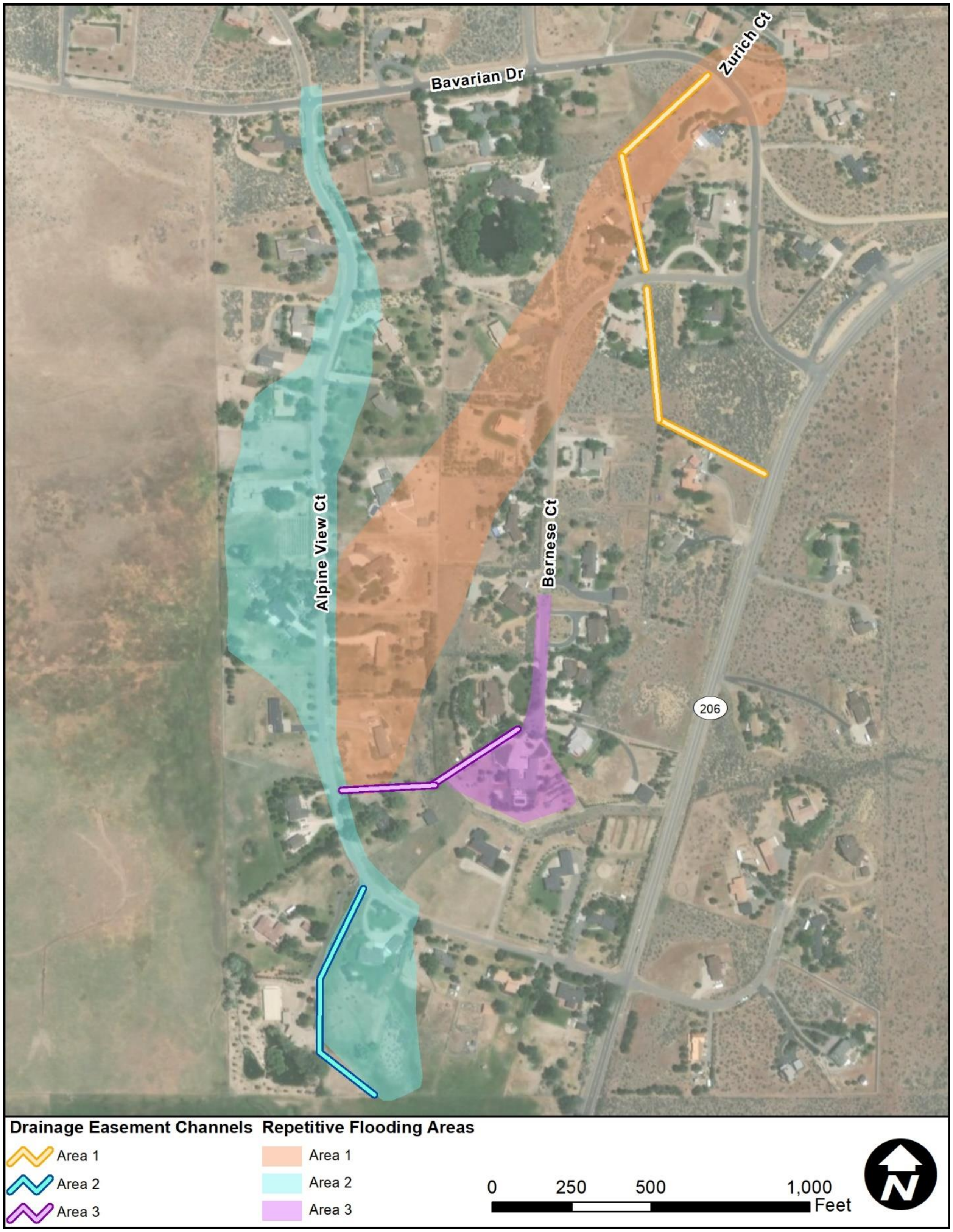

Figure 3-4. Existing drainage easements that impact areas of concern

3.1.1 25-Year, 24-Hour Storm

The FLO-2D results indicate a peak discharge of 15 cfs downstream of Bavarian Drive that includes both flow in the drainage easement channel and flow that overtops Bavarian Drive. A new 24" culvert that extends from the northeast corner of the intersection to the drainage easement would eliminate flows overtopping Bavarian Drive and keep the offsite flows within an improved easement channel.

Table 3-1 lists the mitigation alternative improvements that are recommended for the 25-year 24-hour storm event. Note: that these channels provide minimal freeboard in these concepts; channel geometries were computed to minimize velocities to reduce the need for bed and bank protection.

3.1.2 100-Year, 6-Hour Storm

The FLO-2D results indicate a peak discharge of 65 cfs downstream of Bavarian Drive that includes both flow in the drainage easement channel and flow that overtops Bavarian Drive. New 36" culverts (x3) that extend from the northeast corner of the intersection to the drainage easement would eliminate flows overtopping Bavarian Drive and keep the offsite flows within an improved easement channel.

Table 3-2 lists the mitigation alternative improvements that are recommended for the 100-year 6-hour storm event. Note: that these channels provide minimal freeboard in these concepts; channel geometries were computed to minimize velocities to reduce the need for bed and bank protection.

Table 3-1. Mitigation Alternatives for 25-Year, 24-Hour Storm

ID	Location	Discharge Estimate (cfs)	Structure Type	Estimated Size (or Purpose)
2	NE corner of Zurich Court and Bavarian Drive	9	Culvert	1 x 24" CMP
1	NE corner of Zurich Court and Bavarian Drive	-	Basin	Provide small basin to provide headwater for culvert
3	Drainage Easement Segment #1 (Bavarian Drive to direction change)	15	Drainage Easement Channel Improvement	3 ft Bottom Width 2:1 Side Slopes 11 ft Top Bank Width 2 ft Depth
4	Drainage Easement Segment #2(direction change to Bernese Court)	20	Drainage Easement Channel Improvement	3 ft Bottom Width 2:1 Side Slopes 11 ft Top Bank Width 2 ft Depth
5	Bernese Court	20	Culvert	2 x 24" CMP
6	Drainage Easement Segment #3 (downstream of Bernese Court)	20	Drainage Easement Channel Improvement	3 ft Bottom Width 2:1 Side Slopes 11 ft Top Bank Width 2 ft Depth
7	Jack's Valley Road West Drainage Channel upstream of Alpine View Ct.	30	Channel Improvement	4 ft Bottom Width 2:1 Side Slopes 12 ft Top Bank Width 1 ft Depth
8	Alpine View Ct. and Jack's Valley Road West Intersection	30	Culvert	2 x 36" CMP
9	Jack's Valley Road West Drainage Channel downstream of Alpine View Ct.	30	Channel Improvement	4 ft Bottom Width 2:1 Side Slopes 12 ft Top Bank Width 1 ft Depth
10	Alpine View Ct. and Jack's Valley Road East Intersection	70	Culvert	2 x 48" CMP
11	Jack's Valley Road East Drainage Channel[1]	70	Channel Improvement	10 ft Bottom Width 2:1 Side Slopes 18 ft Top Bank Width 1 ft Depth
12	Jack's Valley Road Culvert	70	Culvert	2 x 48" CMP

1. Channel velocities are >5 feet/second, thus bed and bank erosion protection are needed.

Table 3-2. Mitigation Alternatives for 100-Year, 6-Hour Storm

ID	Location	Discharge Estimate (cfs)	Structure Type	Estimated Size (or Purpose)
2	NE corner of Zurich Court and Bavarian Drive	35	Culverts	3 x 36” CMP
1	NE corner of Zurich Court and Bavarian Drive	-	Basin	Provide small basin to provide headwater for culvert
3	Drainage Easement Segment #1 (Bavarian Drive to direction change)	65	Drainage Easement Channel Improvement	6 ft Bottom Width 2:1 Side Slopes 14 ft Top Bank Width 1.5 ft Depth
4	Drainage Easement Segment #2 (direction change to Bernese Court)	71	Drainage Easement Channel Improvement	8 ft Bottom Width 2:1 Side Slopes 16 ft Top Bank Width 1.6 ft Depth
5	Bernese Court	71	Culverts	2 x 48” CMP
6	Drainage Easement Segment #3 (downstream of Bernese Court)	71	Drainage Easement Channel Improvement	8 ft Bottom Width 2:1 Side Slopes 16 ft Top Bank Width 1.6 ft Depth
7	Jack’s Valley Road West Drainage Channel upstream of Alpine View Ct.	71	Channel Improvement	8 ft Bottom Width 2:1 Side Slopes 16 ft Top Bank Width 1.5 ft Depth
8	Alpine View Ct. and Jack’s Valley Road West Intersection	71	Culvert	3 x 48” CMP
9	Jack’s Valley Road West Drainage Channel[1] downstream of Alpine View Ct.	71	Channel Improvement	8 ft Bottom Width 2:1 Side Slopes 16 ft Top Bank Width 1.5 ft Depth
10	Alpine View Ct. and Jack’s Valley Road East Intersection	150	Culvert	3 x 48” CMP
11	Jack’s Valley Road East Drainage Channel[1]	150	Channel Improvement	12 ft Bottom Width 2:1 Side Slopes 20 ft Top Bank Width 1.5 ft Depth
12	Jack’s Valley Culvert	150	Culvert	3 x 48” CMP
1. Channel velocities are >5 feet/second, thus bed and bank erosion protection are needed.				

3.2 AREA 2

The FLO-2D results indicate overtopping of the intersection of Bavarian Drive and Alpine View Court for both the 25-year and 100-year storms. The modeling also indicates that the present drainage ditches along Alpine View Court are not sufficient to contain the 25-year storm runoff resulting in overtopping and adverse flooding of adjacent properties.

3.2.1 25-Year, 24-Hour Storm

The FLO-2D results indicate a discharge of approximately 30 cfs that overtops Bavarian Drive and enters the drainage ditches, despite an existing 18” culvert. Mitigation alternatives for Area 2 include new culverts at the Bavarian Drive/Alpine View Court intersection, improvements to the east drainage ditch along Alpine View Court, and a new culvert at Alpine View court and southwest drainage easement (see Figure 3-4).

Table 3-3 lists the mitigation alternative improvements that are recommended for the 25-year, 24-hour storm event. Note: that these channels provide minimal freeboard in these concepts; channel geometries were computed to minimize velocities to reduce the need for bed and bank protection.

Table 3-3. Mitigation Alternatives for 25-Year, 24-Hour Storm

ID	Location	Discharge Estimate (cfs)	Structure Type	Estimated Size (or Purpose)
13	NE corner of Bavarian Drive and Alpine View Court	30	Culvert	1 x 36” CMP
14	NE corner of Bavarian Drive and Alpine View Court	-	Basin	Provide small basin to provide headwater for culvert
15	Alpine View Court East Drainage Ditch (Bavarian Drive to approx. 1,140 feet)	30	Drainage Ditch Improvement	2 ft Bottom Width 2:1 Side Slopes 10 ft Top Bank Width 2 ft Depth
16	Alpine View Court East Drainage Ditch (Approx. 1,140 feet to SW drainage easement culvert)	40	Drainage Ditch Improvement	3 ft Bottom Width 2:1 Side Slopes 1 ft Top Bank Width 2 ft Depth
17	Alpine View Court Southwest Drainage Easement Culvert	40	Culvert	1 x 48” CMP
18	Alpine View Court Southwest Drainage Easement Channel	40	Drainage Easement Channel Improvement	2 ft Bottom Width 2:1 Side Slopes 10 ft Top Bank Width 2 ft Depth

3.2.2 100-Year, 6-Hour Storm

The FLO-2D results indicate a discharge of approximately 50 cfs that overtops Bavarian Drive and enters the drainage ditches., despite an existing 18" culvert. Mitigation alternatives for Area 2 include new culverts at the Bavarian Drive/Alpine View Court intersection, improvements to the east drainage ditch along Alpine View Court, and a new culvert at Alpine View court and southwest drainage easement.

Table 3-4 lists the mitigation alternative improvements that are recommended for the 100-year, 6-hour storm event. Note: that these channels provide minimal freeboard in these concepts; channel geometries were computed to minimize velocities to reduce the need for bed and bank protection.

Table 3-4. Mitigation Alternatives for 100-Year, 6-Hour Storm

ID	Location	Discharge Estimate (cfs)	Structure Type	Estimated Size (or Purpose)
13	NE corner of Bavarian Drive and Alpine View Court	50	Culvert	2 x 36" CMP
14	NE corner of Bavarian Drive and Alpine View Court	-	Basin	Provide small basin to provide headwater for culvert
15	Alpine View Court East Drainage Ditch (Bavarian Drive to approx. 1,140 feet)	60	Drainage Ditch Improvement	8 ft Bottom Width 2:1 Side Slopes 16 ft Top Bank Width 2 ft Depth
16	Alpine View Court East Drainage Ditch (Approx. 1,140 feet to SW drainage easement culvert)	80	Drainage Ditch Improvement	14 ft Bottom Width 2:1 Side Slopes 22 ft Top Bank Width 2 ft Depth
17	Alpine View Court Southwest Drainage Easement Culvert	80	Culvert	2 x 48" CMP
18	Alpine View Court Southwest Drainage Easement Channel	80	Drainage Easement Channel Improvement	14 ft Bottom Width 2:1 Side Slopes 22 ft Top Bank Width 2 ft Depth

3.3 Area 3

Area 3 includes the southern-most portion of Bernese Court. Douglas County indicated that the recurring flooding in this area is due to flow accumulation along the eastern roadside ditch which crosses the cul-de-sac and floods the southwest property. The topographic mapping and FLO-2D results indicate this segment of Bernese Court is not impacted by offsite flows. The contributing watershed to this area is approximately 1.8 acres (Figure 3-5). The 100-Year, 6-Hour FLO-2D results indicates minimal runoff within this area, however the impacted property has experienced flood flows across the driveway and into the garage.

There is an existing drainage easement to the northwest of the property (Figure 3-5) that is currently not in-use (Figure 3-6). Note in the photograph that there is no drainage channel along the alignment and note the presence of a utility box in the lower-center of the photograph.

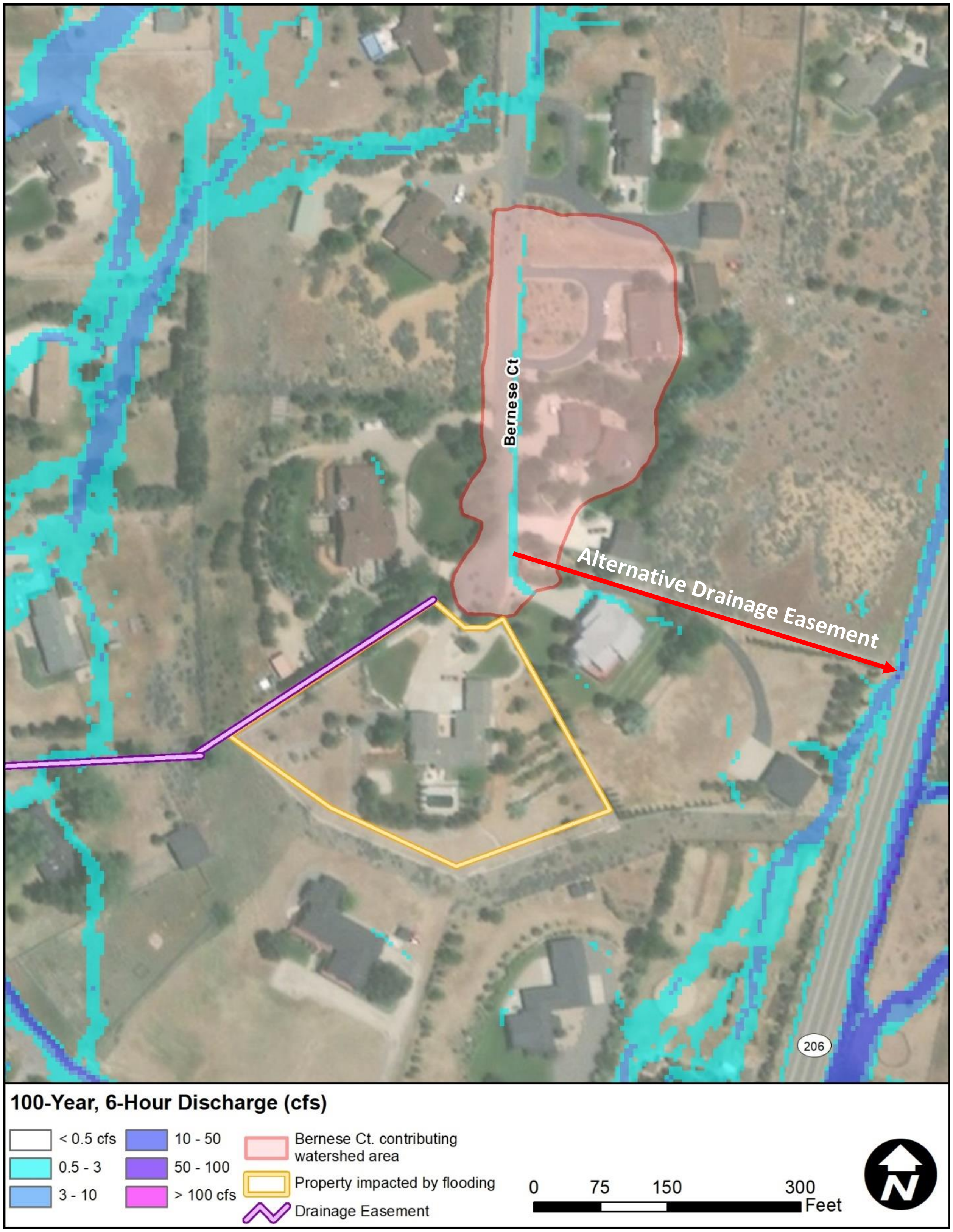

Figure 3-5. Bernese Court drainage area

Figure 3-6. Photograph of drainage easement alignment (view southwest)

3.3.1 25-Year, 24-Hour and 100-Year, 6-Hour Storms

The FLO-2D results indicate a discharge of less than 1 cfs along the east ditch near the end of the cul-de-sac for the 25-year storm and less than 3 cfs for the 100-year storm.

Given the relatively low runoff for this area, the following mitigation alternatives are recommended:

- Construct a concrete valley gutter that extends from the end of the east ditch across the cul-de-sac to the existing easement that can convey the desired discharge (Figure 3-7).
- Construct a drainage channel along the easement that will sufficiently convey approximately 3 cfs to the Alpine View Court eastern ditch channel. This may necessitate moving the utility box outside of the easement area.

Another option would be to consider adding an alternate drainage easement that drains to the Highway 206 (Jacks Valley Road) western channel (see (Figure 3-5). This location would benefit by avoiding the utility box in the existing easement. However, additional easement locations would need to be purchased.

Figure 3-7. Example of a typical valley gutter

3.4 Summary

The primary focus of this study was to develop a comprehensive existing conditions flood risk assessment for the 25-year and 100-year storms, and to evaluate concept-level mitigation alternatives. To that end, the following comments and limitations are provided:

- The proposed mitigation structures in this report represent concept-level alternatives.
- Actual structure sizes and geometries should be re-evaluated during a final design phase.
- This study did not include cost estimates for the proposed alternatives.
- It is recommended that all existing and future drainage easement channels be maintained to avoid vegetation establishment and the accumulation of sediment, both of which will impact the functionality of the channels and culverts.
- There are additional drainage easement channels within the subdivision that are not discussed in this report. Most intercept local (not offsite) drainage, thus have a minimal impact.
- It is recommended that all existing drainage easements are maintained (cleared of vegetation and sediment accumulation) for maximum conveyance.
- In general, the existing drainage easements were utilized for the recommended alternatives. However, one additional easement location was identified for possible future use.
- The proposed channel improvements along the east side of Alpine View Court will necessitate the replacement all current driveway culverts.

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